AFIT/GLM/LAR/93S-32

A COMPARISON OF USERS' AND PROVIDERS' PERCEPTIONS OF CRITICAL SPACELIFT VEHICLE CHARACTERISTICS AND CAPABILITIES

THESIS

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THESIS

Presented to the School of Logistics
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Master of Science in Logistics Management

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Preface

As aircraft maintenance officers, we initially wanted to examine the maintenance and other support activities planned for the space-based systems that will become the Air Force of the future. We discovered that all the wonderful plans for future systems are being held back by a present problem--the lack of capable spacelift vehicles. Upon delving into the literature concerning spacelift vehicles, we soon found that there is no real consensus on what these vehicles should be able to do. We speculated that a potential reason for the lack of consensus is poor communication between spacelift vehicle users and providers. The purpose of this research was to determine whether spacelift vehicle users and providers agreed on the critical characteristics and capabilities for spacelift vehicles. The research was conducted using a statistical analysis of data collected through a survey of users and providers within the military, commercial, and civil sectors. The research indicates that, as a whole, users and providers agree on which spacelift vehicle characteristics and capabilities are critical. However, the military and commercial sectors disagree over the criticality of several characteristics and capabilities.

A number of people helped us during our research. First, we would like to thank our thesis advisors, Dr. Douglas Goetz and Maj Rodney Rice, for their guidance

throughout the research process. We would also like to thank our research sponsors: Dr. William Pursch from the National Contract Management Association; Col Charles Banta from the Launch Systems Division under the Assistant Secretary of the Air Force for Acquisitions; and Mr. Carl Rappaport and Mr. Damon Wells in the U.S. Department of Transportation Office of Commercial Space Transportation. Maj Rick Fennel of the Air Force Ballistic Missile Office, Mr. William Powell of the National Aerospace Plane (NASP) Joint Program Office (JPO), and Dr. William Gaubatz and his staff from the McDonnell Douglas Delta Clipper program helped us develop definitions for spacelift vehicle characteristics and capabilities. Maj Bill West administered the preliminary survey to members of the NASP JPO. Without the gracious participation of the survey respondents, the survey would have been impossible. Finally, we would like to thank our wives, Jennifer and Sheila, for understanding the late nights; supporting us through the frustrating times; sharing the joy of completion; and loving us through it all.

Daws Oslund and Mark Shafer

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Abstract

This study compares spacelift vehicle users' and providers' perceptions of critical spacelift vehicle characteristics and capabilities. Through a literature review, the researchers identified 22 characteristics and capabilities for further study. The researchers then designed a survey to measure the perceived criticality of these 22 characteristics and capabilities. The researchers mailed the survey to military, commercial, and civil spacelift vehicle users and providers and conducted a statistical analysis of the survey results. The primary findings of the study are: 1) the three most critical characteristics and capabilities are reliability, launch cost, and resilience; 2) the three least critical characteristics and capabilities are man-rateable, reusability, and gross lift-off weight; 3) only launch cost has a significantly different mean criticality rating among spacelift vehicle users and providers; and 4) 13 of the 22 characteristics and capabilities have significantly different mean criticality ratings between the military and commercial sectors. The researchers conclude that differences between users' and providers' perceptions are inconsequential, but further study of military and commercial perceptions is necessary.

A COMPARISON OF USERS' AND PROVIDERS' PERCEPTIONS OF CRITICAL SPACELIFT VEHICLE CHARACTERISTICS AND CAPABILITIES

I. Introduction

Overview

Applications of space technology have already provided tangible benefits to mankind, and, as space technology continues to develop, applications that are presently theoretical may one day provide practical benefits as operational systems. However, the use of advanced space technology depends on the successful operation of spacelift vehicles to deploy technology into space. Despite the importance of spacelift vehicle services for future space initiatives, there is no consensus among experts about which spacelift vehicle characteristics and capabilities will promote successful deployment. In particular, differences between what spacelift vehicle users and providers perceive as critical performance characteristics and capabilities may contribute to this lack of consensus. This study compares the critical characteristics and capabilities identified by users with those identified by providers in order to develop a consensus of critical spacelift vehicle characteristics and capabilities.

General Issue and Background

Currently, space technology supports ballistic missile detection, communication, navigation, and remote sensing applications. In orbit since the 1960s, the Defense Satellite Program (DSP) provides tactical warning capability against land- or sea-based missiles (Velocci, 1991:46). According to General Charles Horner, commander of United States Space Command (USSPACECOM), the DSP is useful to warfighters in the Middle East and would be needed if Balkan countries develop missile capability ("Washington Outlook," 1993:19).

A prime example of the use of current space technologies for military communication and navigation purposes was the coalition victory in Operation Desert Storm, what some military leaders have termed "the first space war." Decision-makers relied on information provided by Air Force Space Command's navigation, communication, and weather satellites to make critical decisions. In fact, Global Positioning System satellites supplied navigational information to over 4500 commanders to aid them in making critical decisions ("Air Force Space Command," 1992:78).

Remote sensing involves data collection and transmission by weather, ocean, or land sensing satellites for predictions involving phenomena on Earth. Using data from satellites, improved weather prediction of hurricanes, tornadoes, and monsoons saves thousands of lives and prevents billions of dollars in property damages annually

(Goldman, 1992:176). Remote sensing of the oceans measures water levels and quality, maps ocean currents, estimates the size of fish schools, and tracks ice flows for navigation. Sensing of land masses aids in earthquake prediction, provides information concerning crops, and pin-points geological structures likely to contain mineral ores or reserves (Goldman, 1992:179).

Current military and commercial applications of space technology represent only a few of the many possible uses. Future applications, presently in development, include enhanced missile launch warning, power production and material processing. For instance, the Follow-on Early Warning System (FEWS) will be able to detect both intercontinental and tactical missiles globally. The FEWS will conduct information processing on-board the spacecraft, providing more information and making the data available to operational units faster than DSP (Smith and O'Lone, 1992:69). Also, deuterium (He_3) mining on the moon could provide the quantity of deuterium necessary to produce nuclear power through deuterium fusion. In addition, solar power could be collected by using satellites to gather solar energy, convert it into microwaves, and transmit it to Earth for conversion into electrical power (Graham, 1992a:7-8). Moreover, the near-perfect vacuum and near-zero gravity of the space environment could be used for precision manufacturing of crystals, structures, and pharmaceuticals

in ways it would be impossible to duplicate on Earth (Roland, 1985:48).

These current and future applications of space technology will never reach their full potential nor will they reap their desired benefits unless the current limitations of spacelift vehicles are overcome. Various literary sources identify several limitations of current spacelift vehicles which have hindered the development and optimal employment of space technology. First, are exorbitant launch costs paid by the organizations using the launch systems. These costs are comprised of the purchase price for expendable vehicles, the cost to rebuild the launch support structures, and the salaries for the enormous work forces employed (Payton, 1991:43). Second, the Expendable Launch Vehicles (ELV) presently in use place their payloads in orbit on only 90 percent of the launches (Parrington, 1991:47). This lack of reliability has impeded space exploitation in two ways: 1) it precludes small and medium sized businesses, which could not bear higher launch costs, from pursuing space development; and 2) the destruction or inaccurate positioning of a payload produces setbacks to programs or ventures which require the payload's support (Christensen, 1992:35,41). Finally, the relatively small number of launches provided by current vehicles limits access to space, a phenomena caused, in part, by the limited number of launch pads available to support rockets (Berkowitz 1989-1990:81). As a result, this infrequent

access to space restricts government programs and inhibits efforts of commercial space entrepreneurs (Foley, 1989:118).

Justification

In addition to the benefits that space technology may provide mankind, the nations or consortiums that control space-based resources will capture the economic and military gains provided by space technology, thus making the deployment of space technology a continuing national interest. France, China, and Japan, among others, have realized the potential economic and military windfalls associated with the application of space technology, and have expanded their national space programs accordingly (Clayton, 1988:32). Furthermore, the nations that successfully exploit space technology may have a great deal of influence on international affairs (Graham, 1992a:5).

Concerning possible directions for the U.S. space program, reports sponsored by the National Commission on Space and the National Aeronautics and Space Administration, discussed in Chapter 2, repeatedly emphasize the need for developing new spacelift vehicles to retain American leadership in space. In addition, these reports suggest that agencies responsible for developing future space vehicles must be aware of the user's technological needs and incorporate customer concerns into all vehicle designs. Finally, to enable the greatest application of space technology to user's needs, developers must also continually

assess design capabilities of each generation of spacelift vehicles. Therefore, a comparison of what users and providers of spacelift vehicle services perceive as the critical characteristics and capabilities of spacelift vehicles would help narrow communication gaps between users and providers and offer future design considerations to providers.

Specific Problem

Although U.S. space program literature and reports detail limitations of current spacelift vehicles and important issues in the development of future spacelift vehicles, a user and provider consensus about what comprises the characteristics and capabilities necessary for spacelift vehicle success is not available. This research identifies the spacelift vehicle characteristics and capabilities perceived as critical by users and providers, and then analyzes differences in the users' and providers' perceptions of each characteristic's or capability's criticality.

Research Question

The question that will serve as the focus of this research is: How do the characteristics and capabilities perceived as critical by spacelift vehicle users compare to those identified as critical by providers?

Investigative Questions

The research question will be divided into two sections for investigation: the first concerns the characteristics and capabilities of viable spacelift vehicles; and the second analyzes the data obtained. Two investigative questions develop the first section:

1. What characteristics and capabilities do military, commercial, and civil spacelift vehicle users identify as critical for spacelift vehicles to perform successfully?
2. What characteristics and capabilities do military, commercial, and civil spacelift vehicle providers identify as critical for spacelift vehicles to perform successfully?

The following questions develop the second section:

3. Do differences exist between what users and providers perceive as the critical characteristics and capabilities of spacelift vehicles?
4. Which characteristics and capabilities do users and providers perceive to be the three most critical and three least critical?
5. Are there any correlations between the characteristics and capabilities of spacelift vehicles?

Scope and Limitations

Two constraints formulate the scope of this research. First, the survey population is not inclusive of all spacelift vehicle users and providers. The researchers did not have the means to identify every spacelift vehicle user

and provider from which to select a representative sample. Instead, the researchers relied on the survey sponsors to identify the population of interest for this research. As a result, the population cells were not uniform and only two civil users and two civil providers were included in the survey population. A listing identifying the population for this research is in Appendix A.

Second, the researchers recognize the exploratory nature of this study, and do not intend for the study to be an end in and of itself. Rather, the researchers desire to improve the understanding of spacelift vehicle users and providers perceptions of critical spacelift vehicle characteristics and capabilities. In addition, the researchers provide recommendations for further study in Chapter 5 with the hope that future researchers will advance the knowledge within this subject.

Two limitations exist in the research. First, the research does not include foreign users or providers. Second, the study is limited to medium- to heavy-lift spacelift vehicles. Both limitations are due to restrictions on the researchers' time and funds.

Definitions

For the purpose of this research, the following operational definitions are offered:

Spacelift Vehicle. A vehicle used to transport an object into space.

Spacelift Vehicle Capability. An ability or power that enables a spacelift vehicle to perform a specific function. For the purpose of this study, the following are considered spacelift vehicle capabilities:

All-weather Capability. The ability to launch, operate, and recover a spacelift vehicle despite weather conditions at the launch facility or downrange.

Flexibility. The ability for the vehicle to deploy a variety of payloads to different orbits on different missions.

Lift Capacity. The maximum total payload weight that the vehicle can place in a specific orbit.

Maintainability. The ability to troubleshoot (including integrated diagnostics) and replace components throughout the vehicle regardless of vehicle location with minimal impact on other systems.

Resilience. The ability of the spacelift vehicle program to recover from setbacks and continue launches despite a vehicle failure.

Responsiveness. The ability to expedite launch preparation in response to short notice tasking.

Reusability. The ability to recover and relaunch either the entire vehicle or a core module of the vehicle.

Robustness. The ability of a vehicle to tolerate the failure of a system(s) or adverse circumstance(s) and continue to operate.

Spacelift Vehicle Characteristic. An attribute that describes a spacelift vehicle. For the purpose of this research, the following are considered spacelift vehicle characteristics:

Efficiency. Effective use of resources (i.e. manpower and fuel).

Environmental Impact. The amount of damage inflicted by the vehicle during launch and recovery--to include propellants, exhaust, and noise.

Gross Lift-off Weight. The total mass of the vehicle, payload, and fuel prior to launch (i.e. the total mass that the engines must lift).

Launch Cost. The cost to place a payload into the desired orbit.

Launch Support Personnel. The number of people required to prepare, launch, monitor operations, and recover the vehicle for each launch.

Man Rateable. Possessing sufficient reliability, redundancy, and robustness to minimize catastrophic failure.

Modularity. A design of the vehicle allowing additional or upgraded stages or strap-on boosters to be added to the core of the vehicle.

Operability. The calendar time required to prepare and service a vehicle in preparation for launch.

Payload Size. The maximum payload length, width, and height dimensions that will fit in the vehicle's cargo bay.

Performance. The thrust-to-weight ratio.

Propulsion. The type of propellant used by the engines (i.e. liquid or solid).

Reliability. The percentage of payloads delivered to the correct orbit at the scheduled time.

Safety. Precautions taken to protect from hazards the crew, payload, ground crew, launch facilities, and third party personnel.

Standardized Payload Interface. A design of the cargo bay requiring payloads to meet standardized configurations (to include software interface).

Spacelift Vehicle Services. Integrating the payload with a spacelift vehicle, preparing the vehicle for launch, and conducting launch operations.

Spacelift Vehicle Providers. Organizations that design and produce spacelift vehicles, and furnish spacelift vehicle services in support of users' requirements.

Spacelift Vehicle Users. Organizations that employ spacelift vehicle services for deployment of systems into space.

Thesis Overview

Space technology is an ever-expanding field. Current and future applications of this technology may provide substantial benefits to mankind. However, reaping these benefits depends on successful deployment of spacelift systems. In order to guarantee success, users and providers

of spacelift vehicle services must clearly communicate their requirements and capabilities. This research determines if there are differences in the characteristics and capabilities perceived by users and providers as critical for spacelift vehicle success. Results of this study may be useful in improving communication between users and providers and offering future design considerations to providers.

The next chapter contains a literature review that summarizes reports concerned with the United States space program, specifically spacelift vehicles. Chapter 3 provides a detailed description of the survey methodology used to conduct the research, while Chapter 4 discusses the research findings. Finally, Chapter 5 includes recommendations and conclusions concerning the comparison of characteristics and capabilities supplied by users and providers.

II. Literature Review

Overview

Although volumes of information, studies, and reports about space applications and technology have been written since the late 1950s, the researchers limited their review to literature which discusses spacelift vehicles. Consultation with Lieutenant General Daniel O. Graham (Ret), Director of High Frontier, Inc., yielded a list of pertinent commissioned reports for the researchers to evaluate (Graham, 1992b). The bibliographies of these commissioned reports were reviewed for additional sources. The researchers analyzed the additional reports, searching for those that specifically addressed spacelift issues. The researchers included in the Literature Review all of the reports containing a discussion of spacelift issues.

While each report contains a discussion of spacelift concerns, the diversity of recommendations made from one report to another demonstrates the multifarious and dynamic interests and environment found in the U.S. space program. However, from these various recommendations emerge three common themes throughout the reports: 1) the importance of spacelift vehicles; 2) the presence of inconsistent goals for the U.S. space program; 3) the lack of consensus about critical characteristics and capabilities. This chapter sequentially discusses each theme.

Importance of Spacelift Vehicles

The first common theme identified in the reports involves the recognition of the important role spacelift vehicles play in the U.S. space program. Ride unequivocally voices the necessity of spacelift in declaring that "a space program that can't get to orbit has all the effectiveness of a navy that can't get to sea" (Ride, 1987:39). Three years later, *The Report of the Advisory Committee on the Future of the U.S. Space Program* reinforced this belief by stating that "the most fundamental building block without which there can be no future space program is the transportation system which provides our access to space" (*Report of the Advisory Committee*, 1990:32).

In addition to emphasizing the general need for spacelift, many reports identify specific spacelift requirements necessary to accomplish space program initiatives. From 1969 through 1991, for instance, several reports discussed the types of vehicles necessary to accomplish the specific goals outlined in each report (NASA, 1969; NASA, 1985; National Commission on Space, 1986; Ride, 1987; Synthesis Group, 1991).

Finally, the importance of spacelift vehicles grew to the point that entire reports were dedicated solely to the subject of spacelift, a fact demonstrated by the following. *Launch Options for the Future* presented Congress several spacelift options that could be initiated (U.S. Congress, Office of Technology Assessment, 1988a). *Reducing Launch*

Operations Costs: New Technologies and Practices focusses on operations options which can be employed to reduce launch costs (U.S. Congress, Office of Technology Assessment, 1988b). *Access to Space: The Future of U.S. Space Transportation Systems* contains discussions concerning the number and type of spacelift vehicles required (U.S. Congress, Office of Technology Assessment, 1990). *The National Space Policy Directive 4 (NSPD 4): National Space Launch Strategy* established a strategy not for the space program in general, but for space launch in particular (Bush, 1991). Finally, *The Future of the U.S. Space Launch Capability* specifically recommends the development of a new spacelift program to meet future needs (Vice President's Space Policy Advisory Board, 1992). Each of these cited reports either call for a general spacelift capability or identify a specific vehicle necessary for accomplishing national space goals.

U.S. Space Program Goals

The second theme common to the reports regards the goals for the national space program. Beginning with the National Aeronautics and Space Act of 1958, a clear national space strategy existed (NASA, 1969:35). In 1961, President Kennedy translated that strategy into a specific national goal by committing the U.S. to place a man on the moon and return him safely to Earth within the decade (U.S. Congress. House, 1982:4). Since that time, however, the space program

has operated without an unwavering commitment to specific goals, despite repeated calls for the establishment of national space policy goals.

Insufficient Direction. A common thread running through the reports is a call for identification of and commitment to goals for the national space program. Shortly after the first lunar landing, and fulfillment of President Kennedy's stated national goal, NASA identified the need to determine the future course for the U.S. space program (NASA, 1969:5). A number of reports since 1969 echo NASA's concern over a lack of clear objectives, indicating that national space goals were never set. Congressional testimony highlights the lack of long range goals for the U.S. space program (Flippo, 1981:1). In her report, Ride suggests the need for long-range direction for the space program (Ride, 1987:7). The Defense Science Board found shortfalls in the National Launch Strategy, and highlighted the lack of a consistent statement of requirements (Defense Science Board, 1990:35). The Congressional Office of Technology Assessment recommended a "national dialog" to establish the future course for the U.S. space program and the means to accomplish program goals (U.S. Congress, Office of Technology Assessment, 1990:4). The authors of the *Report of the Advisory Committee on the Future of the U.S. Space Program* noted the nation's lack of consensus on what the goals of the space program should be (*Report of the Advisory Committee*, 1990:19). According to the Vice

President's Space Policy Advisory Board, "the National Space Launch strategy is not being implemented in a cohesive, coordinated, and integrated manner" (Vice President's Space Policy Advisory Board, 1992:19).

At the same time these requests for clear U.S. space program goals were made, several of the reports included in this literature review were suggesting specific goals. The following is a synopsis of these reports' suggestions.

Suggestions. In *America's Next Decades in Space*, NASA suggests that the U.S. should pursue specific goals in the following areas: Earth orbital manned space flight, lunar exploration, planetary exploration, astronomy and physics, life sciences, space applications, and space technology (NASA, 1969:37-43).

Through *Pioneering the Space Frontier*, the National Commission on Space detailed a space program witn five primary objectives:

> 1. Advancing the understanding of [the] planet, [the] Solar System, and the Universe.
> 2. Exploring, prospecting, and settling the Solar System.
> 3. Stimulating the space enterprise for the direct benefit of the people of Earth.
> 4. Advancing technology across the broad spectrum to assure timely availability of critical capabilities.
> 5. Creating and operating systems and institutions to provide low-cost access to the space frontier. (National Commission on Space, 1986:5)

The *NASA: 1986 Long-Range Program Plan* provides a detailed discussion of the programs NASA intended to pursue from 1986 until the turn of the century, including the following topics: 1) space science and applications (to

include study of the distant universe, exploration of the near universe, Earth and its environment, life sciences, satellite communications, and microgravity science and applications); 2) space flight; 3) space station; 4) space tracking and data systems (to include space networks, ground networks, communications and data systems, research and development for advanced systems, and advanced studies); and 5) space research and technology (NASA, 1985:II-4 to II-16).

In 1987, Ride recommended the following initiatives as space program goals:

1. Mission to planet earth.
2. Exploration of the solar system.
3. Outpost on the moon.
4. Humans to Mars. (Ride, 1987:7)

In *Access to Space: The Future of U.S. Space Transportation Systems*, the U.S. Congress, Office of Technology Assessment provided six potential space program options for the future:

1. Continue existing NASA and DoD space programs.
2. Limit the growth of NASA's activities for humans in space.
3. Establish a lunar base or send crews to Mars.
4. Continue the trends of launching increasingly heavier payloads and/or pursue an aggressive Strategic Defense Initiative test program.
5. Develop the capability to launch small and intermediate size payloads quickly and efficiently to support DoD needs.
6. Deploy a full-scale space-based ballistic missile defense system and/or dramatically increase the number and kind of other military space activities. (U.S. Congress, Office of Technology Assessment, 1990:21-25)

The *Report of the Advisory Committee on the Future of the U.S. Space Program* identified only two goals with

respect to the civil space program: a mission to planet Earth aimed at providing a greater understanding of Earth; and a mission from planet Earth with an emphasis on space exploration (*Report of the Advisory Committee*, 1990:26-29).

In *America at the Threshold*, the Synthesis Group establishes four interrelated objectives:

1. Mars Exploration.
2. Science Emphasis for the Moon and Mars.
3. The Moon to Stay and Mars Exploration.
4. Space Resource Utilization. (Synthesis Group, 1991:5)

In order to put these objectives into perspective, the report identifies the following "six visions [to] guide and direct [the] space efforts (Synthesis Group, 1991:2)."

1. Knowledge of our Universe.
2. Advancement in Science and Engineering.
3. United States Leadership.
4. Technologies for Earth.
5. Commercialization of Space.
6. Strengthened U.S. Economy. (Synthesis Group, 1991:2)

The *National Space Policy Directive 4 (NSPD 4): National Space Launch Strategy* identifies four primary elements of the National Space Launch Strategy:

1. Ensuring that existing space launch capabilities, including support facilities, are sufficient to meet U.S. Government maned and unmanned space launch needs.
2. Developing a new unmanned, but man-rateable, space launch system to greatly improve national launch capability with reductions in operating costs and improvements in launch system reliability, responsiveness, and mission performance.
3. Sustaining a vigorous space launch technology program to provide cost-effective improvements to current launch systems, and to support development of advanced launch capabilities, complementary to the new launch system.

4. Actively considering commercial space launch needs and factoring them into decisions on improvements in launch facilities and launch vehicles. (Bush, 1991:1)

Despite some differences, a great degree of commonality exists between the reports' suggestions. The suggested goals identified can be summarized into four primary objectives: 1) better understanding of the Earth; 2) lunar exploration (to include a lunar base); 3) planetary exploration; and 4) space exploitation to improve life on Earth.

Despite the repeated appeals for nation space program goals, and the concurrent suggestion of basically the same four potential objectives, a clearly defined national space policy was not established.

Lack of Consensus

The third common theme is that each report discusses a unique set of spacelift vehicle characteristics and capabilities. Appendix B identifies the characteristics and capabilities discussed in each report. While some similarity exists among the characteristics and capabilities mentioned in each report, differences exist from one report to the others in the specific characteristics and capabilities discussed. The following list serves as a compilation of all the spacelift vehicle characteristics and capabilities discussed in the reports researched for this study.

Spacelift Vehicle Characteristics and Capabilities.

The numbers provided in the "Number of Reports" column reflect the number of reports, out of the 15 reports reviewed, that discussed the characteristic or capability.

Characteristics/Capabilities	Number of Reports
Reliability	12
Cost	8
Flexibility	8
Reusability	8
Lift capacity	7
Safety	7
Manned	6
Man-rateable	6
Expendable	5
Payload capacity	5
Propulsion	5
Efficiency	4
Launch personnel	4
Low cost	4
Maintainability	4
Responsiveness	4
Robustness	4
Unmanned	4
Launch rate	3
Minimized turn time	3
Operability	3
Performance	3
Standardized interface	3
Launch on schedule	2
Mass	2
Modularity	2
Operational availability	2
Payload cost	2
Redundant systems	2
Resilient	2
Ability for system to accept upgrades to existing components	1
Abort principles	1
Access probability	1
Adaptable for on-orbit servicing, maintenance, and repair	1
Aerobraking	1
All-weather capability	1
Automated cargo handling and vehicle erection	1
Autonomous systems	1
Best-value procurement	1
Built-in test equipment	1
Capacity	1

Characteristics/Capabilities	Number of Reports
Complexity	1
Control	1
Economic	1
Engines	1
Environmental concerns	1
Fuel tanks	1
Guidance	1
Lightweight and durable cryogenic tanks	1
Lightweight and durable thermal protection	1
Materials	1
Mission duration considerations	1
Number of stages	1
Operationally simple	1
Payload-to-liftoff mass ratio	1
Rapid refueling	1
Reduced sensitivity to changes in launch conditions	1
Structures	1
Surge capability	1
Survivable	1
Versatile	1

This large list of characteristics and capabilities is evidence of the lack of consensus that exists among those involved with the space program. In addition, the fact that 31 of the 61 characteristics and capabilities, listed above, are discussed in only one report provides further evidence of a lack of consensus. Even the most commonly discussed characteristic or capability, reliability, was not identified in all of the reports. In addition, three characteristics and capabilities tied for the second most commonly discussed, yet these three were mentioned in only half of the reports. This lack of consensus served as the impetus for the researchers' study of spacelift vehicle user and provider perceptions of critical spacelift vehicle characteristics and capabilities.

Chapter Summary

This chapter identified three themes running through the literature that addresses spacelift vehicles. The first common theme is the recognition of the importance of spacelift vehicles. The second theme concerns the identification of insufficient direction within the U.S. space program and concurrent suggestions for national space program goals. The third theme involves a lack of consensus among the reports as to the importance of spacelift vehicle characteristics and capabilities.

Chapter 3 provides an explanation of the methodology used by the researchers to conduct their study. Included in Chapter 3 is an explanation of how the list of characteristics and capabilities was reduced to a manageable level for use in the survey.

III. Methodology

Overview

This chapter discusses the methods used to gather the data necessary to answer the investigative questions of this study. First, the chapter reviews the design of the study. Next, it addresses survey justification and survey development, then discusses questionnaire administration, reliability, and validity. Finally, this chapter identifies data analysis issues associated with this research.

Research Design

The research was accomplished in two stages. The first stage was an introductory literature search designed to more clearly define the research problem and identify specific measurement questions. The focus of the literature search centered on reports addressing spacelift vehicle issues. These reports were summarized, and the spacelift characteristics and capabilities discussed in each report were extracted for further study. Those characteristics and capabilities presented in a minimum of two reports were compiled into a list of common characteristics and capabilities.

The information gathered during the first stage provided the basis for the second stage of the research--a formal study comprised of a survey and data analysis. The survey was used to measure what users and providers of spacelift vehicle services perceived as the important

characteristics and capabilities of spacelift vehicles. The researchers used statistical analysis of data obtained from the survey to determine whether users and providers agreed or disagreed on their perceptions of critical spacelift vehicle characteristics and capabilities.

Population. The population for the survey was diverse and included military, commercial, and civil users and providers of spacelift services. Table 1 indicates the number of respondents from each segment of the population.

TABLE 1

SURVEY POPULATION CLASSIFICATION

	User	Provider
Military	13	8
Commercial	9	4
Civil	2	2

The target population consisted of organizations that either provide or use the services of medium to heavy-lift spacelift vehicles. Members of the target population were identified by the research sponsors in the U.S. Department of Transportation, Office of Commercial Space Transportation; and the Launch Systems Division under the Assistant Secretary of the Air Force for Acquisitions. Given the limited total population of interest, the researchers determined a survey of the entire population was feasible, thus eliminating the requirement to select a sample of the population. The survey respondents were

guaranteed anonymity during this study and were informed of the study's objective prior to receipt of the survey. As a result, disguising the objectives of the study was unnecessary (Emory and Cooper, 1991:139). After the data had been gathered through the survey, the researchers performed different methods of statistical analysis (discussed later in this chapter) to answer each investigative question. Thus, all five of the investigative questions were answered using the survey methodology.

Survey Justification

Because the researchers needed to reach dispersed groups of individuals in an effective manner, mail surveys provided the most appropriate technique. To that end, the researchers selected a survey format based on the advantages presented by Stone: low cost, mail distribution, uniform stimulus to all subjects, and anonymity for respondents (Stone, 1978:63).

Survey Development

In an effort to establish greater credibility for the survey, the researchers obtained sponsorship of the questionnaire from the National Contract Management Association (NCMA), the Department of Transportation Office of Commercial Space Launch, and the Assistant Secretary of the Air Force Office of Space Launch Acquisition.

Identification of the Characteristics and Capabilities.

After compiling the list of spacelift vehicle

characteristics and capabilities (see Chapter 2), the researchers sought to identify those that were critical. Only those characteristics and capabilities discussed in two or more reports were given further consideration for use in the survey. To ensure that all critical characteristics and capabilities were included in the survey, the researchers analyzed those characteristics and capabilities only discussed in one report to determine if they could be combined with another, and thus used in the survey. For example, both "all-weather capability" and "reduced sensitivity to changes in launch conditions" were discussed in only one report. However, the researchers judged that they were similar enough to be included in the survey under the topic "all-weather capability." To prevent redundancy, the researchers performed a similar analysis with the characteristics and capabilities mentioned in two or more reports. Similar characteristics and capabilities were grouped under one heading. For example, "manned," "unmanned," and "man-rateable" all related to the same concept and were included under the single topic "man-rateable." The following list represents the characteristics and capabilities used in the survey. Definitions for these terms, as they appeared in the final survey, were provided in Chapter 1.

Characteristic/Capability

All-weather capability
Efficiency
Environmental impact
Flexibility
Gross liftoff weight
Launch cost
Launch support personnel
Lift capacity
Maintainability
Man-rateable
Modularity
Operability
Payload size
Performance
Propulsion
Reliability
Resilience
Responsiveness
Reusability
Robustness
Safety
Standardized payload interface

Definition Composition. Based on a review of the reports and discussions with spacelift experts, the researchers determined that the definitions of the terms used on the survey were not inherently obvious or consistent. As a result, the researchers decided that definitions would have to be provided to ensure uniform responses. Accordingly, the researchers composed preliminary definitions based on information found in the reviewed reports and other literature. The preliminary definitions were then delivered to members of the U.S. Air Force Ballistic Missile Office, the National Aerospace Plane Joint Program Office, and McDonnell Douglas Delta Clipper Office for verification and revision. The researchers selected these offices because each represented a segment

(military, civil, commercial) of the future target population of the survey, and members of each office had been previously contacted by the researchers. The researchers then integrated suggestions from the aforementioned offices into revised definitions of each characteristic and capability, which were then used for the preliminary survey.

Preliminary Survey. The preliminary survey incorporated three sections (see Appendix C). The first section provided questions designed to measure the respondents' perception of the criticality of twenty-two spacelift vehicle characteristics and capabilities. These questions were closed-ended, asking the respondents to rank the criticality of each characteristic and capability based on the definition provided. The researchers chose the closed-ended approach for these questions based on the uniformity of responses and direct transmittal of the data from the questionnaire to the computer (Babbie, 1973:141). The researchers formatted the answers in an ordinal scale to facilitate a ranking response (Adams and Schvaneveldt, 1991:156). Of the ordinal scale formats available, the researchers chose the Likert scale because the researchers intended to elicit the perceptions, or attitudes, of the respondents. According to Rea and Parker, "the Likert scale works particularly well in the context of a series of questions that seek to elicit attitudinal information about one specific subject matter" (Rea and Parker, 1992:74).

Using the Likert scale, respondents were asked to indicate their perception of the criticality of each characteristic and capability on a scale ranging from 1 to 5, 1 being not critical, 3 being neutral, and 5 being a critical response.

The second section, questions 23 and 24, was designed to collect demographic information using closed-ended questions. The third section of the survey involved only one question, number 25, but gave respondents an opportunity to identify critical characteristics and capabilities not mentioned earlier. This question was open-ended in order to facilitate greater freedom of subjective expression and minimize researcher bias (Adams and Schvaneveldt, 1991:200; Balsley and Clover, 1979:129).

Pretesting. Researchers commonly validate surveys by pretesting the instrument using colleagues, a representative portion of the sample, or a sub-sample of the population before administering the questionnaire to the full sample (Emory and Cooper, 1991:376). Pretesting ensures that the survey is formulated adequately through an evaluation of question content, question wording, response structure, and question sequence. The researchers pretested the preliminary survey by administering it to AFIT faculty, members of the National Aerospace Plane Joint Program Office, and the survey sponsors. Pretest respondents were chosen based either on their expertise with respect to survey development or on their experience with the characteristics and capabilities of spacelift vehicles.

Comments made by the pretest participants were evaluated for incorporation into the final version of the survey (see Appendix E). First, several of the pretest participants indicated that they did not understand the definitions provided or offered alternative definitions. As a result, the researchers revised several of the characteristic and capability definitions to promote clarity. Second, one of the survey sponsors expressed concern over the limited number of responses offered on the Likert scale, and suggested that it be expanded. In response, the researchers expanded the Likert scale from a range of five responses to seven responses to allow greater latitude in response. The following is a representation of the Likert scale as it appeared on the final survey:

Very Uncritical						Very Critical
1	2	3	4	5	6	7

Third, confusion over the demographic information requested in questions 23 and 24 and a suggestion by one of the survey sponsors resulted in a complete revision of questions 23 and 24 (see Appendix E). The revised questions attempt to reinforce qualitatively the respondent's perception of the three most critical and three least critical characteristics and capabilities. The questions were changed to open-ended responses to once again facilitate greater freedom of subjective expression and to prevent researcher bias. Based

on results from the preliminary survey, no changes were necessary for Question 25.

Questionnaire Administration

Via telephone, the researchers contacted each organization identified by the sponsors as spacelift vehicle users or providers. During the telephone calls, the researchers described the objectives of their research, requested each organization's participation in the survey, and asked them to identify a representative of the organization to respond to the survey. Each organization contacted agreed to participate.

The researchers chose mail as the mode of survey communication because the spacelift vehicle users and providers selected to participate were literally spread from one coast of the United States to the other. The cost savings for researchers and convenience for respondents associated with mail-out surveys were primary factors in the decision to mail the questionnaire, even though mail surveys often take longer to collect and typically show lower response rates (Rea and Parker, 1992:9).

To counteract these negative effects, the researchers employed Dillman's Total Design Method for survey administration. Accordingly, the researchers attempted to convince the participants that a problem, the lack of consensus as to critical spacelift vehicle characteristics and capabilities, existed and that their help was required

to develop such a consensus (Dillman, 1978:162). All correspondence with the participants included the recipient's name and address; additionally, the letters were signed individually, dated with the date of mailing, and mailed first class (Dillman, 1978:163).

First, an introductory letter printed on NCMA letterhead and signed by the NCMA sponsor was sent to each participant (see Appendix D). Five business days later, the researchers sent a survey, a cover letter, and a self-addressed stamped return envelope to each respondent via first class mail (see Appendix E). Two weeks after the survey package was mailed, a follow-on letter was sent to each respondent (see Appendix F), thanking those experts who had responded, and reminding those who had not responded of their importance in the research effort (Dillman, 1978:163). Four weeks after mailing the survey package, the researchers telephoned those participants who had still not responded, verifying receipt of the survey material and requesting prompt return of the survey. Those participants who had misplaced or not received the survey were mailed a duplicate of the original survey package. The researchers extended Dillman's prescribed response waiting period from six weeks to ten weeks in order to increase the response rate (Dillman, 1978:163). Through the researchers' persistent telephone calls, all of the surveys were returned by the end of the tenth week for a 100 percent response rate.

Reliability

The degree to which a measurement tool, in this study the survey, is free of random error determines the instrument's reliability (Emory and Cooper, 1991:185). Measurement instruments which provide consistent results when implemented in different conditions and different times are judged to be reliable (Emory and Cooper, 1991:185; Adams and Schvaneveldt, 1991:86-87). One of the key measures of a tool's reliability is internal consistency (Long and others, 1985:92). Internal consistency is an assessment of the consistency within items on the same survey. The internal consistency of the questionnaire used in this study was estimated using Cronbach's Coefficient Alpha (Emory and Cooper, 1991:187; Nunnally, 1978:230).

Most reliability tests require the comparison of at least two test administrations. Unfortunately, time constraints for both researchers and respondents prohibited the researchers from administering the questionnaire twice or drafting two questionnaires. However, according to Nunnally, Cronbach's Coefficient Alpha can estimate the correlation of an actual test with a hypothetical alternative form of that test of the same length measuring the same subject (Nunnally, 1967:197). After the surveys were returned, the researchers used the Statistical Analysis System (SAS) software on the AFIT network to compute the Coefficient Alpha for the questionnaire.

Nunnally also states that in the early stages of research, reliabilities of 0.70 or higher will suffice (Nunnally, 1978:245). The Coefficient Alpha calculated for the survey used in this research was 0.87, indicating that the survey administered was reliable.

Validity

Simon and Burstein relate the importance of validity to a survey's success through the following statement: "Reliability is necessary for adequate measurement, but not sufficient. An adequate measure must also be valid" (Simon and Burstein, 1985:210). The internal validity of an instrument identifies whether the instrument measures what it was intended to, and is related to the information being sought, the population being measured, and the criterion used to make inferences from the data gathered (Long and others, 1985:90). The internal validity of the survey used in this research was established based on content validity.

The completeness of the tool, whether it represents "adequate coverage of a given topic," is referred to as content validity (Emory and Cooper, 1991:180). Content validity is determined based on the judgement of the researchers and a panel of experts (Emory and Cooper, 1991:180). In this study, the content validity of the questionnaire was established through a qualitative analysis by the researchers, AFIT faculty, members of the National

Aerospace Plane (NASP) program office, and survey sponsors during pretesting.

Data Analysis

After receiving the questionnaire responses, the researchers compiled the data into a database structured for use with SAS software (see Appendix G). The database was structured so that analysis could be conducted on the data as a whole; the fields of user or provider; the sectors of military, commercial, or civil; and the segments of military users, civil users, commercial users, military providers, civil providers, or commercial providers.

SAS software was used for each portion of the data analysis. First, the mean response for each question was calculated to identify the perceived criticality of each characteristic and capability for the population as a whole, each field, and each segment. A mean response ranging from 1.0 to 3.5 indicated noncritical; a mean response ranging from 3.51 to 4.5 indicated neutrality; and a mean response ranging from 4.51 to 7.0 indicated critical.

Second, the researchers conducted an analysis of variance (ANOVA), including the Tukey procedure for multiple comparisons at a 90% confidence interval, to determine whether there was a difference in perceived criticality (mean response) between users and providers at both the field and segment levels. In order to accomplish the ANOVA in SAS, the researchers performed the general linear models

(GLM) procedure. GLM is necessary when "there are unequal numbers of observations" between the segments being compared, and in this study, differences existed between the number of respondents queried in each segment (SAS User's Manual, 1988:555). The Tukey procedure is used to determine whether a statistically significant difference exists between mean responses of several groups (Williams, 1992:17-11).

Third, the Pearson Product Moment Coefficient of Correlation (*r*) was calculated for each pair of characteristics and capabilities. According to McClave and Benson, *r* measures the strength of the relationship between two variables (McClave and Benson, 1991:481). The interpretation of the correlation coefficient values was based on Kidder's discussion of the strength of correlational relationships:

> A correlation of less than .15 (either positive or negative) generally means that there is not much relationship between the variables at all. For a correlation between .15 and .30, the relationship would generally be considered weak, and between .30 and .50, you would call the relationship moderate. A correlation between .50 and .70 would be called a strong relationship, and over .70 (either positive or negative) the relationship would be called very strong. (Kidder, 1981:329)

Chapter Summary

This chapter identified the specific research design implemented by the researchers to collect data for the study. A survey was developed to measure spacelift vehicle users and providers' perception of the criticality of

spacelift vehicle characteristics. The survey was administered to all member organizations of the target population identified by the survey sponsors. Survey administration consisted of mailing introductory letters, the survey package, and follow-up letters to all participants, and telephoning late respondents to improve the response rate. Data collected through the survey was analyzed using SAS software.

Chapter Four reports the findings of the data analysis, including a discussion of the characteristic and capability means, differences between the means, and the correlation analysis calculated for the survey data.

IV. Data Analysis

Overview

The purpose of this study was to: 1) identify the spacelift vehicle characteristics and capabilities perceived as critical by spacelift vehicle users; 2) identify the spacelift vehicle characteristics and capabilities perceived as critical by spacelift vehicle providers; 3) determine whether differences exist between the perceptions of spacelift vehicle users and providers; 4) identify the three most critical and three least critical characteristics and capabilities perceived by spacelift vehicle users and providers; and 5) measure the strength of correlations between the spacelift vehicle characteristics and capabilities.

As explained in the previous chapter, the researchers wrote a SAS program to obtain the mean and standard deviation of each characteristic's or capability's criticality. The SAS program calculated each characteristic's or capability's criticality for each of the following groups of respondents: the entire population, fields (users and providers), sectors (military, commercial, and civil), and segments (military users, military providers, commercial users, commercial providers, civil users, and civil providers). In addition, the SAS program determined whether a statistically significant difference existed between the responses provided within each

population classification. The SAS program also accomplished a correlation analysis on the characteristics and capabilities for the entire population. This chapter discusses data obtained through the survey, including the SAS statistical analysis.

First, the chapter discusses the characteristics' and capabilities' mean criticality according to the population classifications. Second, significant differences between the characteristic and capability criticality means provided by population groups will be identified. Third, the chapter presents the results of the correlation analysis, identifying strong relationships between characteristics and capabilities. Fourth, the responses to survey questions 23 and 24 are discussed. Finally, the chapter lists additional characteristics and capabilities identified by the respondents.

Characteristic and Capability Means

The first step in the statistical analysis was the computation of the criticality mean and standard deviation of each characteristic and capability for the different population classifications. A mean response ranging from 1.0 to 3.5 indicated the respondents perceived the characteristic or capability to be noncritical; a mean response ranging from 3.51 to 4.5 indicated neutrality; and a mean response ranging from 4.51 to 7.0 indicated the characteristic or capability was judged to be critical.

Entire Population. Table 2 provides the mean and standard deviation for each characteristic or capability based on the responses from the entire population.

TABLE 2

CHARACTERISTIC/CAPABILITY MEANS FOR THE ENTIRE POPULATION

Characteristic/Capability	Mean	Std Dev
Reliability	6.5526	0.7240
Launch cost	6.3158	0.9136
Resilience	6.0811	0.8621
Robustness	5.6216	1.4972
Safety	5.5676	1.6080
Operability	5.3784	1.5157
Payload size	5.3243	1.1069
Std payload interface	5.3158	1.2757
Maintainability	5.2703	1.2834
Responsiveness	5.2703	1.6098
Lift capacity	5.1111	1.3686
Min launch support personnel	4.8611	1.5884
Flexibility	4.8158	1.5397
Efficiency	4.7027	1.4116
Modularity	4.6316	1.5320
Environmental impact	4.4737	1.7666
All-weather capability	4.0541	1.5625
Propulsion	3.7297	1.7583
Performance	3.6571	1.8934
Gross lift-off weight	3.2162	1.7342
Reusability	2.8421	1.6850
Man-rateable	2.5526	1.7660

The population of respondents identified 15 of the 22 characteristics and capabilities as critical, with reliability, launch cost, and resilience being the three most critical. Environmental impact, all-weather capability, propulsion, and performance received neutral ratings, indicating the population was unsure about the criticality. Only three characteristics or capabilities were perceived by the population as noncritical--gross lift-

off weight, reusability, and man-rateable. These three form the three least critical characteristics and capabilities.

User Field. Table 3 provides the means and standard deviations for the characteristics and capabilities based on the responses of spacelift vehicle users.

TABLE 3

CHARACTERISTIC/CAPABILITY MEANS FOR THE USER FIELD

Characteristic/Capability	Mean	Std Dev
Launch cost	6.6667	0.6370
Reliability	6.5417	0.6580
Resilience	6.0435	0.9283
Robustness	5.4583	1.4738
Safety	5.4583	1.6413
Std payload interface	5.3750	1.2790
Operability	5.3043	1.5206
Payload size	5.2917	1.0417
Maintainability	5.2917	1.2676
Lift capacity	5.2500	1.2247
Responsiveness	5.1739	1.9459
Min launch support personnel	4.9130	1.4433
Modularity	4.6667	1.3726
Flexibility	4.6667	1.6594
Efficiency	4.6087	1.2336
Environmental impact	4.1667	1.8337
All-weather capability	4.1250	1.5965
Performance	3.7391	1.9121
Propulsion	3.5000	1.7195
Gross lift-off weight	3.1667	1.5788
Reusability	2.7083	1.4590
Man-rateable	2.5000	1.6940

Users within the population perceived launch cost, reliability, and resilience to be the three most critical characteristics or capabilities. Neutral responses were given for environmental impact, all-weather capability, and performance. Four characteristics and capabilities were deemed noncritical--propulsion, gross lift-off weight,

reusability, and man-rateable. The three least critical characteristics and capabilities, according to users, are gross lift-off weight, reusability, and man-rateable.

Provider Field. Table 4 lists the characteristics' and capabilities' means according to spacelift vehicle providers.

TABLE 4

CHARACTERISTIC/CAPABILITY MEANS FOR THE PROVIDER FIELD

Characteristic/Capability	Mean	Std Dev
Reliability	6.5714	0.8516
Resilience	6.1429	0.7703
Robustness	5.9231	1.5525
Safety	5.7692	1.5892
Launch cost	5.7143	0.9945
Operability	5.5000	1.5566
Responsiveness	5.4286	0.8516
Payload size	5.3846	1.2609
Maintainability	5.2308	1.3634
Std payload interface	5.2143	1.3114
Flexibility	5.0714	1.3281
Environmental impact	5.0000	1.5689
Efficiency	4.8571	1.7033
Lift capacity	4.8333	1.6422
Min launch support personnel	4.7692	1.8777
Modularity	4.5714	1.8277
Propulsion	4.1538	1.8187
All-weather capability	3.9231	1.5525
Performance	3.5000	1.9306
Gross lift-off weight	3.3077	2.0569
Reusability	3.0714	2.0555
Man-rateable	2.6429	1.9457

For the first time, launch cost is not among the top three most critical characteristics and capabilities. Providers perceive reliability, resilience, and robustness to be the three most critical characteristics and capabilities. Neutral responses were given for propulsion and all-weather

capability. Of the providers' four noncritical characteristics and capabilities, the three lowest rated are gross lift-off weight, reusability, and man-rateable.

Military Sector. The means and standard deviations for the characteristics and capabilities according to military members of the population are given in Table 5.

TABLE 5

CHARACTERISTIC/CAPABILITY MEANS FOR THE MILITARY SECTOR

Characteristic/Capability	Mean	Std Dev
Reliability	6.6190	0.5896
Robustness	6.2381	0.9437
Launch cost	6.1429	0.9636
Resilience	6.1429	1.0142
Operability	6.0000	1.0761
Responsiveness	5.8000	1.4726
Maintainability	5.7143	1.0071
Std payload interface	5.7143	1.0071
Safety	5.7143	1.4880
Min launch support personnel	5.5238	1.1670
Payload size	5.3810	1.1170
Flexibility	5.3333	1.1106
Environmental impact	5.3333	1.1547
Lift capacity	5.2857	1.2705
Efficiency	5.0000	1.2649
Modularity	4.6190	1.6576
All-weather capability	4.5238	1.2498
Performance	4.4211	1.6095
Propulsion	4.3810	1.3956
Gross lift-off weight	3.5714	1.7768
Reusability	3.4762	1.5690
Man-rateable	2.7143	1.7928

According to the military sector, all but five of the characteristics and capabilities are critical. The military sector perceived reliability, robustness, and launch cost to be the three most critical characteristics and capabilities. Of the three population sectors, the military sector is the

only one to include robustness among the top three most critical characteristics and capabilities, and the only sector not rating launch cost as the singular most critical. Neutral responses were given for performance, propulsion, and gross lift-off weight. Only two characteristics and capabilities were deemed noncritical--reusability and man-rateable. The military sector believes gross lift-off weight, reusability, and man-rateable are the three least critical characteristics and capabilities.

Commercial Sector. The commercial sector perceives only nine characteristics and capabilities to be critical, with launch cost, reliability, and resilience being the three most critical. The commercial sector is the only sector to include resilience among the three most critical characteristics and capabilities. The commercial sector provided the highest number of neutral responses, rating maintainability, responsiveness, operability, flexibility, efficiency, and minimum launch support personnel as neither critical nor noncritical. Of the seven characteristics and capabilities perceived to be noncritical, gross lift-off weight, reusability, and man-rateable are believed to be the least critical. The commercial sector is the only sector to rate a characteristic's or capability's criticality lower than 2.0. The military and commercial sectors agree on the three least critical characteristics and capabilities. Table 6 provides the means and standard deviations of the responses from the commercial sector.

TABLE 6

CHARACTERISTIC/CAPABILITY MEANS FOR THE COMMERCIAL SECTOR

Characteristic/Capability	Mean	Std Dev
Launch cost	6.5385	0.8771
Reliability	6.5385	0.8771
Resilience	6.0833	0.5149
Payload size	5.2308	1.2352
Safety	5.0000	1.8586
Std payload interface	4.9231	1.4979
Lift capacity	4.9167	1.5643
Robustness	4.7500	1.8647
Modularity	4.5385	1.5607
Maintainability	4.4167	1.4434
Responsiveness	4.3846	1.6602
Operability	4.3077	1.7022
Flexibility	4.0769	1.7541
Efficiency	3.9167	1.5643
Min launch support personnel	3.6364	1.8586
All-weather capability	3.2500	1.8647
Environmental impact	3.1538	1.8640
Propulsion	2.6667	1.9228
Performance	2.5833	1.8320
Gross lift-off weight	2.4167	1.6214
Reusability	1.6923	1.1094
Man-rateable	1.5385	0.7763

Civil Sector. Members of the population employed in the civil sector perceive launch cost, safety, and reliability to be the three most critical characteristics and capabilities. The civil sector is the only sector to include safety among the three most critical characteristics and capabilities. Standardized payload interface, flexibility, environmental impact, all-weather capability, and gross lift-off weight are deemed as neither critical nor noncritical. Of the civil sector's three least critical characteristics and capabilities--propulsion, performance, and reusability--the only one common to the military and

commercial sectors is reusability. Table 7 provides the means and standard deviations for characteristic and capability criticality according to the civil sector.

TABLE 7

CHARACTERISTIC/CAPABILITY MEANS FOR THE CIVIL SECTOR

Characteristic/Capability	Mean	Std Dev
Launch cost	6.5000	0.5774
Safety	6.5000	1.0000
Reliability	6.2500	0.9574
Operability	5.7500	0.9574
Resilience	5.7500	0.9574
Efficiency	5.5000	0.5774
Maintainability	5.5000	1.0000
Responsiveness	5.5000	1.0000
Payload size	5.3333	0.5774
Modularity	5.0000	0.8165
Man-rateable	5.0000	1.4142
Robustness	5.0000	1.4142
Min launch support personnel	4.7500	0.5000
Lift capacity	4.6667	1.5275
Std payload interface	4.5000	1.2910
Flexibility	4.5000	2.0817
Environmental impact	4.2500	1.7078
All-weather capability	4.0000	1.4142
Gross lift-off weight	3.7500	1.2583
Propulsion	3.5000	1.7321
Performance	3.2500	2.0616
Reusability	3.2500	2.2174

Military User Segment. According to military users, the three most critical characteristics and capabilities are reliability, launch cost, and resilience. Unlike the military sector, the military user segment does not include robustness among the three most critical characteristics and capabilities, replacing it with resilience. Military users are neutral about performance, propulsion, and reusability. The three least critical characteristics and capabilities

are reusability, gross lift-off weight, and man-rateable. Although rated in a different order, the military users agree with the military sector on the three least critical characteristics and capabilities. Table 8 provides the means and standard deviations for the military users' perceptions of characteristic and capability criticality.

TABLE 8

CHARACTERISTIC/CAPABILITY MEANS
FOR THE MILITARY USER SEGMENT

Characteristic/Capability	Mean	Std Dev
Reliability	6.4615	0.6602
Launch cost	6.4615	0.7763
Resilience	6.0000	1.5417
Robustness	5.9231	1.0377
Operability	5.9167	1.3114
Responsiveness	5.9167	1.7299
Maintainability	5.7692	1.0127
Std payload interface	5.7692	1.0127
Min launch support personnel	5.6154	0.6504
Safety	5.4615	1.6641
Flexibility	5.3846	1.1929
Lift capacity	5.3077	1.1094
Payload size	5.0769	1.0377
Environmental impact	5.0000	1.2247
All-weather capability	4.7692	1.0919
Efficiency	4.6154	1.2609
Modularity	4.5385	1.5607
Performance	4.3333	1.8257
Propulsion	4.0000	1.4720
Reusability	3.6154	1.1929
Gross lift-off weight	3.4615	1.4607
Man-rateable	2.8462	1.9081

Military Provider Segment. Table 9 gives the characteristic and capability means and standard deviations based on the military provider responses.

TABLE 9

CHARACTERISTIC/CAPABILITY MEANS
FOR THE MILITARY PROVIDER SEGMENT

Characteristic/Capability	Mean	Std Dev
Reliability	6.8750	0.3536
Robustness	6.7500	0.4629
Resilience	6.3750	0.7440
Operability	6.1250	0.6409
Safety	6.1250	1.1260
Environmental impact	5.8750	0.8345
Payload size	5.8750	1.1260
Launch cost	5.6250	1.0607
Efficiency	5.6250	1.0607
Maintainability	5.6250	1.0607
Responsiveness	5.6250	1.0607
Std payload interface	5.6250	1.0607
Min launch support personnel	5.3750	1.7678
Flexibility	5.2500	1.0351
Lift capacity	5.2500	1.5811
Propulsion	5.0000	1.0690
Modularity	4.7500	1.9086
Performance	4.5714	1.2724
All-weather capability	4.1250	1.4577
Gross lift-off weight	3.7500	2.8176
Reusability	3.2500	2.1213
Man-rateable	2.5000	1.6903

Of the eighteen characteristics and capabilities military providers deem critical, reliability, robustness, and resilience are the three most critical. The military providers are the only population segment not to include launch cost among the top three most critical characteristics and capabilities. Their rating of launch cost as the eighth most critical characteristic or capability, contributed to the exclusion of launch cost among the top three for the provider field. Military providers are neutral on the criticality of all-weather capability and gross lift-off weight. Military providers

perceive gross lift-off weight, reusability, and man-rateable to be the three least critical characteristics and capabilities, which is in agreement with the military sector.

Commercial User Segment. Table 10 provides the characteristic and capability means and standard deviations according to the commercial users within the population.

TABLE 10

CHARACTERISTIC/CAPABILITY MEANS
FOR THE COMMERCIAL USER SEGMENT

Characteristic/Capability	Mean	Std Dev
Launch cost	6.8889	0.3333
Reliability	6.8889	0.3333
Resilience	6.1250	0.3536
Payload size	5.5556	1.1304
Lift capacity	5.4444	1.3333
Safety	5.3333	1.8028
Robustness	5.1111	1.9003
Std payload interface	5.0000	1.5811
Modularity	4.8889	1.2693
Maintainability	4.6667	1.4142
Operability	4.4444	1.5899
Efficiency	4.3750	1.3025
Flexibility	4.0000	1.8708
Responsiveness	4.0000	1.8708
Min launch support personnel	3.8750	1.8851
All-weather capability	3.1111	1.9003
Performance	3.0000	1.9365
Environmental impact	2.8889	2.0883
Propulsion	2.6667	2.0000
Gross lift-off weight	2.5556	1.6667
Reusability	1.6667	1.0000
Man-rateable	1.5556	0.7265

According to commercial users, there are ten critical characteristics and capabilities, with launch cost, reliability, and resilience being the three most critical.

Commercial users are neutral in their perception of operability, efficiency, flexibility, responsiveness, and minimum launch support personnel. Commercial users believe seven of the characteristics and capabilities are noncritical--all-weather capability, performance, environmental impact, propulsion, gross lift-off weight, reusability, and man-rateable. Although commercial users believe a larger number of the characteristics and capabilities are noncritical, their three least critical are consistent with other groups within the population.

Commercial Provider Segment. Commercial providers consider only five characteristics and capabilities to be critical--resilience, launch cost, reliability, responsiveness, and standardized payload interface. The commercial provider segment is the population group with least number of critical characteristics and capabilities, but the three most critical characteristics and capabilities remain consistent with the commercial field and are not largely different from other groups. Commercial providers are neutral on nine characteristics and capabilities and perceive eight to be noncritical. The three least critical characteristics and capabilities according to commercial providers are gross lift-off weight, reusability, and man-rateable. Table 11 lists the means and standard deviations for the commercial providers' responses.

Civil User Segment. Of the nine characteristics and capabilities civil users perceive as critical, launch cost,

TABLE 11

CHARACTERISTIC/CAPABILITY MEANS
FOR THE COMMERCIAL PROVIDER SEGMENT

Characteristic/Capability	Mean	Std Dev
Resilience	6.0000	0.8165
Launch cost	5.7500	1.2583
Reliability	5.7500	1.2583
Responsiveness	5.2500	0.5000
Std payload interface	4.7500	1.5000
Payload size	4.5000	1.2910
Flexibility	4.2500	1.7078
Safety	4.0000	2.0000
Operability	4.0000	2.1602
Environmental impact	3.7500	1.2583
Modularity	3.7500	2.0616
Maintainability	3.6667	1.5275
Robustness	3.6667	1.5275
All-weather capability	3.6667	2.0817
Lift capacity	3.3333	1.1457
Efficiency	3.0000	1.8257
Min launch support personnel	3.0000	2.0000
Propulsion	2.6667	2.0817
Gross lift-off weight	2.0000	1.7321
Reusability	1.7500	1.5000
Man-rateable	1.5000	1.0000
Performance	1.3333	0.5774

resilience, responsiveness, and safety have the highest rating. The civil users segment is the only group to give launch cost a mean criticality rating of 7.0 (the maximum attainable). The small number of respondents in the civil user segment, two, contributed to the high rating for launch cost. The civil user segment is the population segment with the largest number of neutral responses, ten. The three characteristics and capabilities civil users consider noncritical also form the three least critical--performance, flexibility, and reusability. The civil user segment is one of two population segments that do not include man-rateable

among the three least critical characteristics and capabilities. Table 12 provides the mean and standard deviation of each characteristic and capability according to civil users.

TABLE 12

CHARACTERISTIC/CAPABILITY MEANS
FOR THE CIVIL USER SEGMENT

Characteristic/Capability	Mean	Std Dev
Launch cost	7.0000	0.0000
Resilience	6.0000	1.4142
Responsiveness	6.0000	1.4142
Safety	6.0000	1.4142
Efficiency	5.5000	0.7071
Operability	5.5000	0.7071
Payload size	5.5000	0.7071
Reliability	5.5000	0.7071
Maintainability	5.0000	1.4142
All-weather capability	4.5000	0.7071
Environmental impact	4.5000	0.7071
Man-rateable	4.5000	0.7071
Modularity	4.5000	0.7071
Min launch support personnel	4.5000	0.7071
Std payload interface	4.5000	0.7071
Gross lift-off weight	4.0000	0.0000
Propulsion	4.0000	0.0000
Robustness	4.0000	0.0000
Lift capacity	4.0000	1.4142
Performance	3.5000	2.1213
Flexibility	3.0000	1.4142
Reusability	1.5000	0.7071

<u>Civil Provider Segment</u>. The civil provider segment is the only population segment to provide the highest attainable rating for reliability and safety. The civil provider segment also contained only two respondents, which contributed to the highest attainable ratings and increased the possibility for ties within ratings. The most critical

characteristics and capabilities (including ties) according to the civil providers are reliability, safety, launch cost, lift capacity, maintainability, flexibility, robustness, and operability.

Because ties forced the inclusion of a greater number of entries in the "three most critical" list, the civil provider segment's most critical list included several characteristics and capabilities that were not in the most critical lists of other population groups. As both respondents are members of NASA, the unique inclusion of safety within the three most critical characteristics and capabilities may be attributable to NASA's unfortunate experience with the space shuttle Challenger. The civil providers are neutral on only two characteristics and capabilities--standardized payload interface and environmental impact. Among the four noncritical characteristics and capabilities, there is another rating tie; the three least critical list includes all four noncritical characteristics and capabilities--all-weather capability, gross lift-off weight, performance, and propulsion. The civil provider segment is the only population group not to include reusability and one of two groups not to include man-rateable among the three least critical characteristics and capabilities. Table 13 gives the civil providers' mean response and standard deviation for each characteristic and capability.

TABLE 13

CHARACTERISTIC/CAPABILITY MEANS
FOR THE CIVIL PROVIDER SEGMENT

Characteristic/Capability	Mean	Std Dev
Reliability	7.0000	0.0000
Safety	7.0000	0.0000
Launch cost	6.0000	0 0000
Lift capacity	6.0000	0.0000
Maintainability	6.0000	0.0000
Flexibility	6.0000	1.4142
Robustness	6.0000	1.4142
Operability	6.0000	1.4142
Efficiency	5.5000	0.7071
Modularity	5.5000	0.7071
Resilience	5.5000	0.7071
Man-rateable	5.5000	2.1213
Payload size	5.0000	0.0000
Min launch support personnel	5.0000	0.0000
Responsiveness	5.0000	0.0000
Reusability	5.0000	1.4142
Std payload interface	4.5000	2.1213
Environmental impact	4.0000	2.8284
All-weather capability	3.5000	2.1213
Gross lift-off weight	3.5000	2.1213
Performance	3.0000	2.8284
Propulsion	3.0000	2.8284

Differences Between Characteristic and Capability Means

The preceding discussion of characteristic and capability mean ratings revealed that the different population groups did not rate the characteristics and capabilities identically. This does not necessarily indicate that a statistically significant difference exists between the mean responses for the fields, sectors, or segments of the population. The second part of the analysis entailed the use of the Tukey procedure and SAS GLM procedure to measure the differences between the mean ratings of the characteristics and capabilities among the

fields, sectors, and segments of the population. Differences between means that were significant at a 90 percent confidence level were identified by the SAS output.

Differences Between Population Fields. Launch cost has the only statistically significant difference between the mean criticality ratings given by users and providers. Users perceive launch cost to be more critical than do providers. Table 14 provides the complete comparison of characteristic and capability mean criticality ratings.

TABLE 14

DIFFERENCE BETWEEN THE CHARACTERISTIC/CAPABILITY MEANS AMONG THE USER AND PROVIDER FIELDS

Characteristic/ Capability	User	Provider	Significant Difference
Launch cost	6.6667	5.7143	Yes
Reliability	6.5417	6.5714	
Lift capacity	5.2500	4.8333	
Man-rateable	2.5000	2.6429	
Reusability	2.7083	3.0714	
Efficiency	4.6037	4.8571	
Payload size	5.2917	5.3846	
Robustness	5.4583	5.9321	
Safety	5.4583	5.7692	
Maintainability	5.2917	5.2308	
Flexibility	4.6667	5.0714	
All-weather capability	4.1250	3.9231	
Environmental impact	4.1667	5.0000	
Min launch support personnel	4.9130	4.7692	
Gross lift-off weight	3.1667	3.3077	
Modularity	4.6667	4.5714	
Operability	5.3043	5.5000	
Performance	3.7391	3.5000	
Propulsion	3.5000	4.1538	
Responsiveness	5.1739	5.4286	
Resilience	6.0435	6.1429	
Std payload interface	5.3750	5.2143	

Because only one significant difference exists between these fields, the researchers decided to examine similarities between the perceptions. Table 15 lists the ranks of each characteristic's and capability's mean criticality for both the user and provider fields.

TABLE 15

MEAN CRITICALITY RANKS FOR USERS AND PROVIDERS

Characteristic/Capability	User Rank	Provider Rank
Launch cost	1	5
Reliability	2	1
Resilience	3	2
Robustness	4	3
Safety	5	4
Std payload interface	6	10
Operability	7	6
Payload size	8	8
Maintainability	9	9
Lift capacity	10	14
Responsiveness	11	7
Min launch support personnel	12	15
Modularity	13	16
Flexibility	14	11
Efficiency	15	13
Environmental impact	16	12
All-weather capability	17	18
Performance	18	19
Propulsion	19	17
Gross lift-off weight	20	20
Reusability	21	21
Man-rateable	22	22

The ranking of mean criticality is very similar between the user and provider fields. The same characteristics and capabilities are ranked in the top five for both fields. Were it not for the difference in perceptions of launch cost criticality, the top five would be identical. Users and providers also identify the same top 15 characteristics and

capabilities as critical, although providers identify one additional critical characteristic and capability--environmental impact. Finally, users and providers are in complete agreement on the three least critical characteristics and capabilities.

Differences Between Population Sectors. The military and commercial sectors give significantly different criticality ratings to thirteen out of the twenty-two total characteristics and capabilities. In contrast, the commercial and civil sectors disagreed on the criticality of only two characteristics--man-rateable and efficiency--and the military and civil sectors disagreed on only one characteristic--man-rateable. All three sectors disagreed on the criticality of man-rateable. Table 16 reveals the significant differences in mean criticality ratings between the population sectors.

Differences Between Population Segments. With six different population segments and 22 characteristics and capabilities, there could be a total of 330 differences between the segments; in actuality, however, there are a total of only 20 differences. Military users and commercial users had the highest number of differences, with four. Commercial users and commercial providers are the only segments within a population sector to disagree on the criticality of a characteristic or capability. Table 17 highlights the particular differences between the population segments.

TABLE 16

DIFFERENCE BETWEEN THE CHARACTERISTIC/CAPABILITY MEANS AMONG THE MILITARY, COMMERCIAL, AND CIVIL SECTORS

Characteristic/Capability	Military	Commercial	Civil	Significant Differences
Launch cost	6.1429	6.5385	6.5000	
Reliability	6.6190	6.5385	6.2500	
Lift capacity	5.2857	4.9167	4.6667	
Man-rateable	2.7143	1.5385	5.0000	Mil-Comm, Comm-Civ, Mil-Civ
Reusability	3.4762	1.6923	3.2500	Mil-Comm
Efficiency	5.0000	3.9167	5.5000	Mil-Comm, Comm-Civ
Payload size	5.3810	5.2308	5.3333	
Robustness	6.2381	4.7500	5.0000	Mil-Comm
Safety	5.7143	5.0000	6.5000	
Maintainability	5.7143	4.4167	5.5000	Mil-Comm
Flexibility	5.3333	4.0769	4.5000	Mil-Comm
All-weather capability	4.5238	3.2500	4.0000	Mil-Comm
Environmental impact	5.3333	3.1538	4.2500	Mil-Comm
Min launch support personnel	5.5238	3.6364	4.7500	Mil-Comm
Gross lift-off weight	3.5714	2.4167	3.7500	
Modularity	4.6190	4.5385	5.0000	
Operability	6.0000	4.3077	5.7500	Mil-Comm
Performance	4.4211	2.5833	3.2500	Mil-Comm
Propulsion	4.3810	2.6667	3.5000	Mil-Comm
Responsiveness	5.8000	4.3846	5.5000	Mil-Comm
Resilience	6.1429	6.0833	5.7500	
Std paylaod interface	5.7143	4.9231	4.5000	

TABLE 17

SUMMARY TABLE OF POPULATION SEGMENT DIFFERENCES

	Mil User	Mil Prov	Com User	Com Prov	Civ User	Civ Prov
Mil User		None	Reusable Environmt GLOW Response	Robust Maintain Personel	None	None
Mil Prov	None		Cost Robust Propulsn	Reliable Efficienc Robust	Reliable Robust	None
Com User	Reusable Environmt GLOW Response	Cost Robust Propulsn		Reliable	Reliable	Man-rate Reusable
Com Prov	Robust Maintain Personel	Reliable Efficienc Robust	Reliable		None	Man-rate
Civ User	None	Reliable Robust	Reliable	None		None
Civ Prov	None	None	Man-rate Reusable	Man-rate	None	

Table 18 provides a complete list of means and significant differences for the population segments.

Characteristic and Capability Correlations

The two preceding sections highlight differences among the population groups. The researchers also wanted to identify potential relationships among the characteristics and capabilities. Therefore, the researchers included a Pearson moment correlation procedure in the SAS program. As discussed in Chapter 3, correlations less than 0.15 indicate no relationship, between 0.15 and 0.30 indicate a weak relationship, 0.30 to 0.50 a moderate relationship, 0.50 to 0.70 indicate a strong relationship, and greater than 0.70 a very strong relationship (Kidder, 1981:329).

TABLE 18

DIFFERENCE BETWEEN CHARACTERISTIC/CAPABILITY MEANS AMONG POPULATION SEGMENTS

Characteristic/ Capability	Mil-User	Mil-Prov	Comm-User	Comm-Prov	Civ-User	Civ-Prov	Significant Differences
Launch cost	6.4615	5.6250	6.8889	5.7500	7.0000	6.0000	MiP-CoU
Reliability	6.4615	6.8750	6.8889	5.7500	5.5000	7.0000	CoU-CoP, MiP-CoP, CoU-CiU, MiP-CiU
Lift capacity	5.3077	5.2500	5.4444	3.3333	4.0000	6.0000	
Man-rateable	2.8462	2.5000	1.5556	1.5000	4.5000	5.5000	CoU-CiP, CoP-CiP
Reusability	3.6514	3.2500	1.6667	1.7500	1.5000	5.0000	CoU-CiP, CoU-MiU
Efficiency	4.6154	5.6250	4.3750	3.0000	5.5000	5.5000	MiP-CoP
Payload size	5.0769	5.8750	5.5556	4.5000	5.5000	5.0000	
Robustness	5.9231	6.7500	5.1111	3.6667	4.0000	6.0000	MiP-CiU, MiP-CoP, MiU-CoP
Safety	5.4615	6.1250	5.3333	4.0000	6.0000	7.0000	
Maintainability	5.7692	5.6250	4.6667	3.6667	5.0000	6.0000	MiU-CoP
Flexibility	5.3846	5.2500	4.0000	4.2500	3.0000	6.0000	
All-weather capability	4.7692	4.1250	3.1111	3.6667	4.5000	3.5000	
Environmental impact	5.0000	5.8570	2.8889	3.7500	4.5000	4.0000	MiP-CoU, MiU-CoU
Min launch support personnel	5.6154	5.3750	3.8750	3.0000	4.5000	5.0000	MiU-CoU, MiU-CoP
Gross lift-off weight	3.4615	3.7500	2.5556	2.0000	4.0000	3.5000	
Modularity	4.5385	4.7500	4.8889	3.7500	4.5000	5.5000	
Operability	5.9167	6.1250	4.4444	4.0000	5.5000	6.0000	
Performance	4.3333	4.5714	3.0000	1.3333	3.5000	3.0000	
Propulsion	4.0000	5.0000	2.6667	2.6667	4.0000	3.0000	MiP-CoU
Responsiveness	5.9167	5.6250	4.0000	5.2500	6.0000	5.0000	MiU-CoU
Resilience	6.0000	6.3750	6.1250	6.0000	6.0000	5.5000	
Std paylaod interface	5.7692	5.6250	5.0000	4.7500	4.5000	4.5000	

MiU: Military user
CoU: Commercial user
CiU: Civil user

MiP: Military provider
CoP: Commercial provider
CiP: Civil provider

With 22 characteristics and capabilities, the possible number of relationships totals 231. Of these potential relationships, 71 are nonexistent, 65 are weak, 76 are moderate, 18 are strong, and only one relationship is very strong. The strong relationships are listed in Table 19 with their correlation coefficients.

TABLE 19

SUMMARY TABLE OF STRONG RELATIONSHIPS AMONG THE CHARACTERISTICS AND CAPABILITIES

Characteristics/Capabilities	Correlation Coefficient
Safety - Performance	0.68
Gross lift-off weight - Performance	0.64
Min launch personnel - Propulsion	0.59
Gross lift-off weight - Min launch personnel	0.58
Propulsion - Operability	0.58
Propulsion - Performance	0.58
Propulsion - Efficiency	0.57
Responsiveness - Environmental impact	0.56
Maintainability - Robustness	0.55
Reliability - Robustness	0.54
Responsiveness - Operability	0.53
Maintainability - Safety	0.53
Efficiency - Safety	0.53
Maintainability - Reusability	0.52
Payload size - Lift capacity	0.52
Reliability - Safety	0.52
Environmental impact - Operability	0.51
Gross lift-off weight - Safety	0.51

The only relationship that was identified as very strong is between modularity and man-rateable, which has a correlation coefficient of 0.84. Although this statistic does not indicate causality, it is clear that users and providers believe that modularity and man-rateable are linked. While consistent with the Space Shuttle, this relationship is

contrary to current plans for the McDonnell Douglas Delta Clipper and former plans for the National Aerospace Plane. Both designs call for vehicles that are man-rateable yet are not modular. While launch cost is not strongly related to any of the other characteristics or capabilities, it is interesting to note that launch cost is negatively related to 16 of the 21 other characteristics and capabilities. Finally, safety is the characteristic or capability with the greatest number of strong relationships, with five. Table 20 provides a matrix of the Pearson correlation coefficients for each pairing of characteristics and capabilities.

Questions 23 and 24

In questions 23 and 24, the researchers asked the respondents to list the three most critical and three least critical characteristics and capabilities. The researchers intended for the respondents to use only the 22 characteristics and capabilities included in the survey to answer these questions. However, several respondents included several characteristics and capabilities foreign to the survey and some respondents failed to complete these questions. Because all of the respondents did not use the same set of characteristics and capabilities to answer questions 23 and 24, the researchers determined that the survey instrument was flawed. In retrospect, the researchers should have opened Questions 23 and 24 with the

TABLE 20

CHARACTERISTICS/CAPABILITIES CORRELATION ANALYSIS BASED ON THE ENTIRE POPULATION

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. Launch cost	1.00																					
2. Reliability	-.37	1.00																				
3. Lift capacity	.28	.27	1.00																			
4. Man-rateable	-.04	.19	.21	1.00																		
5. Reusability	-.06	.11	.31	.48	1.00																	
6. Efficiency	-.07	.31	.17	.26	.19	1.00																
7. Payload size	.08	.40	.52	.10	.03	.37	1.00															
8. Robustness	-.27	.54	.15	-.08	.33	.44	.18	1.00														
9. Safety	-.26	.52	.29	.38	.21	.53	.40	.47	1.00													
10. Maintainability	-.27	.33	.14	.09	.52	.38	.25	.55	.53	1.00												
11. Flexibility	-.21	.27	.20	.18	.42	.05	.27	.32	.27	.42	1.00											
12. All-weather capability	-.28	.09	-.11	.40	.24	-.08	.00	-.20	-.06	.00	.30	1.00										
13. Environmental impact	-.18	.06	.00	.09	.18	.34	.09	.14	.24	.11	.17	.47	1.00									
14. Min launch personnel	.09	.03	.28	.19	.48	.48	.12	.45	.45	.48	.32	-.03	.35	1.00								
15. Gross lift-off weight	-.06	.30	.22	.49	.26	.46	.13	.15	.51	.35	.19	.08	.39	.58	1.00							
16. Modularity	.27	.20	.26	.84	.16	.26	.15	.00	.23	.22	.08	-.08	.30	.20	.34	1.00						
17. Operability	-.36	.31	-.08	.35	.41	.47	.25	.41	.38	.47	.49	.31	.51	.46	.43	.18	1.00					
18. Performance	-.08	.42	.39	.35	.31	.50	.25	.40	.68	.39	.44	-.08	.34	.50	.64	.25	.49	1.00				
19. Propulsion	-.19	.13	.22	.27	.38	.57	.28	.37	.35	.49	.38	-.08	.18	.59	.49	.13	.58	.58	1.00			
20. Responsive	-.23	.09	-.23	.25	-.05	.24	-.03	-.13	.14	.04	.05	.49	.56	.07	.40	.17	.53	.26	.20	1.00		
21. Resilience	-.03	.14	.08	.10	-.11	.07	.16	.04	.31	.04	.14	-.06	.18	-.05	.22	.33	.13	.37	.09	.27	1.00	
22. Std payload interface	.23	-.08	.30	.19	.48	.15	.09	.13	.06	.35	.32	-.06	.02	.39	.18	.36	.09	.18	.34	-.13	.38	1.00

phrase, "Of the 22 characteristics and capabilities included in this survey..."

Because the survey instrument was flawed, the researchers determined that the data collected was invalid. Consequently, the responses to questions 23 and 24 were not used to determine the three most critical and three least critical characteristics and capabilities. Instead, the researchers used the means calculated by SAS to answer Investigative Question 4.

Question 25

The researchers asked the respondents to list any additional characteristics or capabilities they considered critical, or worthy of consideration. Data collected with this question was not intended for substantial use within this study. Instead, future researchers studying this subject can use the additional characteristics and capabilities in other studies. Table 21 lists the additional characteristics and capabilities mentioned in response to question 25 and the number of times each was identified.

Chapter Summary

This chapter provided an analysis of the data collected through the research survey. The researchers provided the criticality means for the characteristics and capabilities according to each population group. The researchers used the criticality means to identify the three most critical

TABLE 21

SUGGESTIONS FOR ADDITIONAL CHARACTERISTICS/CAPABILITIES

Characteristic/Capability	Number
Environment placed on the payload (thermal, vibration, acoustic, and g-load)	4
Increased design margins	3
Clean payload handling area	2
Launch pad commonality	2
Location of launch site	2
Reduced order time	2
Ability to satisfy special payload requirements	1
Adequate testing	1
Aircraft-like operability	1
Compatibility with past and future vehicles	1
Daily meetings	1
Electrical and mechanical interfaces	1
Flight termination system	1
Guards	1
Guidance and navigation	1
Impact of vehicle safety requirements on payload	1
Incremental lift capability	1
Launch vehicle acceleration	1
Multiple payload capability	1
No pogo effects	1
Power subsystem	1
Pre-launch preparations	1
Reliable payload/vehicle separation	1
Restartable upper stage	1
Software	1
Structure	1
Transport carriers	1
Troubleshooting team	1

and three least critical characteristics and capabilities according to each population grouping. Based on SAS program output, the researchers revealed the statistically significant differences between criticality means among the population fields, sectors, and segments. The correlation analysis resulting from the SAS program provided the basis for the determination of relationships between pairs of characteristics and capabilities. Finally, the researchers

discussed their decision not to use the data collected in questions 23 and 24 of the survey and provided a listing of additional characteristics and capabilities identified by the respondents.

In the next chapter, the researchers provide the answers to the five investigative questions obtained through this research. In addition, the researchers discuss the lessons learned through this research process and make suggestions for future research.

V. Findings, Conclusions, and Recommendations

Overview

In this chapter, the researchers review the specific problem and the research question, and, using the findings from the data analysis, provide answers to the investigative questions. In addition, the researchers discuss their conclusions about the research and recommend areas for further study.

Review

A large number of potential applications for space-based resources exist. All of these applications have one specific similarity: they cannot be fully exploited until sufficient spacelift capability exists to completely deploy and service the systems.

Specific Problem. Although U.S. space program literature and reports detail limitations of current spacelift vehicles and important issues in the development of future spacelift vehicles, a user and provider consensus about what comprises the characteristics and capabilities necessary for spacelift vehicle success is not available. This research analyzes differences in the characteristics and capabilities perceived by users and providers as critical for spacelift vehicle success.

Research Question. The question that serves as the focus of this research is: How do the characteristics and

capabilities perceived as critical by spacelift vehicle users compare to those identified as critical by providers?

Findings

In order to answer the investigative questions, the researchers conducted a statistical analysis of data collected through a survey, written for use in this research. To accomplish the statistical analysis, the researchers wrote a SAS program to calculate the mean criticality ratings for each of the spacelift vehicle characteristics and capabilities included on the survey. The researchers determined that a mean criticality rating of 4.51 or greater indicates that the respondents perceive the characteristic or capability to be critical. The SAS program calculated the mean criticality according to each of the population fields, sectors, and segments. The Tukey procedure within the SAS program used these means to determine whether statistically significant differences, at a 90 percent confidence level, existed among the means within each population classification. Finally, the SAS program calculated correlations between each pairing of the characteristics and capabilities.

Investigative Question One. The first investigative question is: What characteristics and capabilities do military, commercial, and civil spacelift vehicle users identify as critical for spacelift vehicles to perform successfully?

This question was addressed to the entire user field as well as the population segments within the user field. Of the 22 possible characteristics and capabilities, the user field, as a whole, identified 15 as critical, with launch cost being the most critical. Most of the characteristics and capabilities identified as critical were expected by the researchers; however, two identified as not critical were intriguing. First, reusability, which could serve to reduce launch cost, was not included among those characteristics and capabilities identified as critical. This appears contradictory to the fact that launch cost is identified as the most critical characteristic or capability. Second, despite growing concerns over the Earth's environment, environmental impact is not perceived by spacelift vehicle users to be a critical characteristic or capability.

The military user segment identifies more critical characteristics and capabilities, 17, than the other spacelift vehicle users. Concern exists among "watchdog groups" that the military frequently overdesigns weapon systems to be the ultimate in technology rather than just good enough to perform their missions (Gregory, 1989:94). The large number of characteristics and capabilities identified by military users as critical illustrates that this practice may be evident in the space program as well. Ultimately, this reflects that the military sector may not be subject to the same level of budgetary constraints as the other spacelift vehicle users. While military users

identify a large number of critical characteristics and capabilities, man-rateable is not included. This fact is unexpected at first glance, given that military personnel have served as crew members on numerous spacelift platforms from the inception of the space program. However, the military extensively uses expendable launch vehicles and may be realizing that a man-rateable vehicle is a luxury, not a necessity.

Commercial users only identify ten and civil users believe only nine of the characteristics and capabilities are critical. The greater the number of critical characteristics and capabilities a spacelift vehicle possesses, the greater the cost will be. Because commercial users are interested in limiting costs in order to increase profits, it is reasonable to expect that they would identify a lesser number of critical characteristics and capabilities than the military sector, which is not profit motivated. The researchers did not anticipate, however, that the civil users would identify even fewer critical characteristics and capabilities than the commercial users. The researchers expected the civil users to fall more in line with the military, as the civil sector is also government funded.

Table 22 presents a summary of the characteristics and capabilities that spacelift vehicle users perceive to be critical.

TABLE 22

SUMMARY TABLE OF USER PERCEPTIONS

	Population Users	Military Users	Commercial Users	Civil Users
Launch cost	X	X	X	X
Reliability	X	X	X	X
Lift capacity	X	X	X	
Man-rateable				
Reusability				
Efficiency	X	X		X
Payload size	X	X	X	X
Robustness	X	X	X	
Safety	X	X	X	X
Maintainability	X	X	X	X
Flexibility	X	X		
All-weather capability		X		
Environmental impact		X		
Min launch personnel	X	X		
GLOW				
Modularity	X	X	X	
Operability	X	X		X
Performance				
Propulsion				
Responsiveness	X	X		X
Resilience	X	X	X	X
Std payload interface	X	X	X	

<u>Investigative Question Two</u>. The second investigative question is: What characteristics and capabilities do

military, commercial, and civil spacelift vehicle providers identify as critical for spacelift vehicles to perform successfully?

This question was presented to segments within the provider field as well as the entire provider field. On the whole, the providers identify 16 characteristics and capabilities as critical--one more than those identified by the population users. The additional characteristic or capability identified by the providers is environmental impact. It is plausible that providers are held accountable for the environmental impact of spacelift vehicles and are, therefore, subject to greater criticism than users for any damage done to the environment. If that is the case, it is understandable that providers would perceive their spacelift vehicles' environmental impact to be critical. In addition, like the population users, the population providers did not include reusability as a critical characteristic or capability despite the inclusion of launch cost.

Of all the providers in the population, the military providers identify the greatest number of critical characteristics and capabilities. As with the military users, this list of 18 critical characteristics and capabilities suggests that military providers are eager to emphasize the latest technology over mission necessity. In addition, military providers are the only population segment to identify performance and propulsion in their list of critical characteristics and capabilities.

Table 23 provides the characteristics and capabilities that spacelift vehicle providers perceive to be critical.

TABLE 23

SUMMARY TABLE OF PROVIDER PERCEPTIONS

	Population Provs	Military Provs	Commercial Provs	Civil Provs
Launch cost	X	X	X	X
Reliability	X	X	X	X
Lift capacity	X	X		X
Man-rateable				X
Reusability				X
Efficiency	X	X		X
Payload size	X	X		X
Robustness	X	X		X
Safety	X	X		X
Maintainability	X	X		X
Flexibility	X	X		X
All-weather capability				
Environmental impact	X	X		
Min launch personnel	X	X		X
GLOW				
Modularity	X	X		X
Operability	X	X		X
Performance		X		
Propulsion		X		
Responsiveness	X	X	X	X
Resilience	X	X	X	X
Std payload interface	X	X	X	

Of the four categories listed in Table 23, the commercial provider segment is the most unexpected. Commercial providers identified only five of the 22 characteristics and capabilities as critical. At first glance, the researchers did not expect commercial providers to be as financially constrained as commercial users. However, upon further reflection, it is clear that commercial providers are also profit motivated. The greater the number of characteristics and capabilities emphasized in the design of a spacelift vehicle, the higher the cost and the lower the profit. Also, the higher the cost, the more difficult marketing the vehicle would be.

Like their military counterparts, the civil providers identified a relatively large number of critical characteristics and capabilities. Among their 16 critical characteristics and capabilities, civil providers include man-rateable and reusability. Civil providers are the only population segment to suggest these two characteristics and capabilities as critical. Their inclusion of man-rateable and reusability are certainly reflective of the presence of the Space Shuttle as the civil sector's primary spacelift vehicle.

Investigative Question Three. The third question asks: Do differences exist between what users and providers perceive as the critical characteristics and capabilities of spacelift vehicles?

Providers identify one more critical characteristic and capability than do users--environmental impact. However, the difference in the mean criticality rating for environmental impact is not statistically significant. Table 14 (Chapter 4) provides a list of the characteristics and capabilities whose differences between mean criticality for the user and provider fields are statistically significant at a 90 percent confidence level. The only characteristic or capability with a significant difference in mean criticality ratings is launch cost. Even though the mean criticality ratings are significantly different, both users and providers identify launch cost as a critical spacelift vehicle characteristic or capability. Users perceive launch cost to be the most critical characteristic or capability, whereas providers rate launch cost as the fifth most critical. Based on the lack of consensus about spacelift vehicle characteristics and capabilities discovered during their literature review, the researchers expected to find several significant differences in the mean criticality rating provided by users and providers. As a result, the researchers are very surprised that the analysis yielded only one significant difference in user and provider perceptions of characteristic and capability criticality. Overall, differences between the user and provider fields were minimal.

Military users and military providers are very similar in their characteristic and capability criticality ratings.

This is confirmed in Table 17 (Chapter 4), which shows that no significant differences exist between military users and providers.

Table 17 also indicates that no significant differences exist between civil users and civil providers. This is unexpected, given that civil users identify nine critical characteristics and capabilities while civil providers identify 16. Small cell sizes for civil users and civil providers, 2 in each cell, may contribute to the absence of statistically significant differences.

The only significant difference between the population segments within a population sector, as indicated in Table 17, occurs between the commercial users and commercial providers. Commercial users perceive reliability to be more critical than do commercial providers; however, both segments perceive reliability to be critical. It is understandable that both segments believe reliability to be critical because vehicle reliability impacts the business operations of each segment. The researchers believe that reliability is more critical for users because an errant or destroyed vehicle results in a greater setback for the user than it does for the provider. The lack of significant differences between the segments within each population sector reinforces the preceding comment that differences between the user and provider fields are minimal.

Based on the results of this study, differences between user and provider perceptions of critical characteristics and capabilities are inconsequential.

Investigative Question Four. The fourth question is: Which characteristics and capabilities do users and providers perceive to be the three most critical and three least critical?

As discussed in Chapter 4, the mean criticality ratings calculated by the SAS program were used to determine users' and providers' perceptions of the three most critical and three least critical characteristics and capabilities. Table 24 provides these rankings for each field.

TABLE 24

THE MOST CRITICAL CHARACTERISTICS AND CAPABILITIES

Users	Providers
1. Launch cost	1. Reliability
2. Reliability	2. Resilience
3. Resilience	3. Robustness

The results indicated in the table are very similar and the researchers believe that the differences that do exist are understandable. Clearly, providers will be less concerned about launch costs than users. Regardless of the launch cost, the providers will set their prices in order to make a profit. Users, on the other hand, have less control over launch cost and may be unable to make a profit if the cost is too high.

Table 25 provides the users' and providers' perceptions of the three least critical characteristics and capabilities. Due to both the lack of consensus discovered in the literature review and the differences in the three most critical characteristics and capabilities, the

TABLE 25

THREE LEAST CRITICAL CHARACTERISTICS AND CAPABILITIES

Users	Providers
1. Man-rateable	1. Man-rateable
2. Reusability	2. Reusability
3. GLOW	3. GLOW

researchers anticipated that the characteristics and capabilities identified as the three least critical would be different for users and providers. Thus, the researchers are surprised that the three least critical characteristics and capabilities are exactly the same for both user and providers.

Clearly some differences exist between users' and providers' perceptions of critical spacelift vehicle characteristics and capabilities. However, the similarity in the answers to this investigative question lends additional credence to the researchers' previous statement that the differences between users' and providers' perceptions of characteristic and capability criticality are inconsequential.

Investigative Question 5. The final question asks: Are there any correlations between the characteristics and capabilities?

Naturally, correlations exist between different characteristics and capabilities. However, only 18 of the 231 possible pairings of characteristics and capabilities results in a strong relationship and only the relationship between man-rateable and modularity is considered very strong. The researchers expected to see very strong relationships between launch cost and other cost-related characteristics and capabilities, such as efficiency, reliability, reusability, and minimum launch support personnel. Of the top three critical characteristics and capabilities for both users and providers, there are only four strong relationships and zero very strong relationships. Stronger relationships, particularly if negative, could lead to a better understanding of why characteristics and capabilities would be perceived as critical or non-critical. Table 19 (Chapter 4) lists the pairings of characteristics and capabilities with strong relationships.

Conclusions

The researchers used the answers to the investigative questions to answer the research question, which asks: How do the characteristics and capabilities perceived as

critical by spacelift vehicle users compare to those identified as critical by providers?

From the in-depth review of policy statements, Congressional hearings, and commissioned reports, the researchers inferred that a lack of consensus about critical characteristics and capabilities existed between the perceptions of spacelift vehicle users and providers. This inference prompted the researchers to conduct the survey of user and provider perceptions. The researchers expected to see significant differences between what the users and providers perceived as critical. However, Table 14 reveals that spacelift vehicle users and providers only differ significantly on one characteristic or capability. In addition, Table 15 identifies a striking similarity between the user's and provider's mean criticality rankings. This data does not necessarily indicate that a consensus exists between spacelift users and providers, but obviously does not support the researchers' assumption that significant differences exist. The researchers conclude that in aggregate, the differences between spacelift vehicle users' and providers' perceptions of critical spacelift vehicle characteristics and capabilities are minor.

The researchers also inferred from the literature review that significant differences would exist between spacelift vehicle users and providers within sectors of the population. As discussed in Chapter 4, military and civil users have no significant differences with the providers

within their own sectors and commercial users and providers differ significantly only on reliability. This information contradicts the researchers' second inference, and supports the conclusion that only minimal differences exist between spacelift users and providers, even within population sectors.

Although the analysis of differing perceptions between the military, commercial, and civil sectors was not necessary to answer any of the investigative questions, this particular analysis yielded interesting results. As identified in Table 16, the military and commercial sectors differ significantly on 13 of the 22 characteristics and capabilities included in the survey. This finding is important in that the Air Force Space Command has determined that the next generation spacelift system "must satisfy military, civil, and commercial requirements" (Roberts, 1993:8). If the military and commercial sectors do not agree on the critical spacelift vehicle characteristics and capabilities, it may be difficult for the military to meet commercial requirements.

Recommendations

The researchers recommend the following as areas for future study:

1. Significant differences exist between the characteristics and capabilities' mean criticality ratings for the military and commercial sectors of this study's

population. Further research needs to be conducted to verify these differences and to identify methods of reducing differences between the sectors' perceptions.

2. The literature reviewed contained repeated calls for clarification of space program policy and objectives. Perhaps the inadequacy of present vehicles is a result of shifting policy and objectives rather than a lack of consensus between users and providers of spacelift vehicle services. Future research is needed to determine whether changes in space program policy and objectives significantly impact the functionality of spacelift vehicle programs.

3. A few of the respondents chose not to rate some of the characteristics and capabilities due to disagreement with the definitions provided. A formal study is needed to establish uniform definitions for the spacelift vehicle characteristics and capabilities throughout all sectors of the population.

4. Question 25 of this research's survey asked respondents to provide additional critical characteristics and capabilities. Responses to this question, provided in Table 21, should be included in a future study.

5. While spacelift vehicle users and providers may be in relative agreement on spacelift vehicle characteristics' and capabilities' criticality, congruence on specific standards may not exist. Using the characteristics and capabilities identified as critical in this study, a future

study is needed to quantify a range of acceptable values for these critical characteristics and capabilities.

Appendix A

Organizations Participating in the Survey

Space Systems LORAL
3825 Fabian Way
Palo Alto, CA 94303

GTE Spacenet
1700 Old Meadow Rd
McLean, VA 22102

TRW
1 Space Park
Redondo Beach, CA 90278

COMSAT World Systems
950 L'Enfant Plaza S.W.
Washington, D.C. 20024

AT&T
295 N. Maple Ave
Basking Ridge, NJ 07920

Motorola Satellite Communications
Chandler, AZ 85248

Lockheed Missile and Space Company
1111 Lockheed Way
Sunnyvale, CA 94089

Hughes Communication, Inc.
P.O. Box 92424
Los Angeles, CA 90009

INTELSAT
3400 International Drive, N.W.
Washington, D.C. 20008-3098

NASA Expendable Launch Vehicle Office
300 E Street
Washington, D.C. 20546

NASA Shuttle Operations
300 E Street
Washington, D.C. 20546

National Oceanographic and Atmospheric Administration
NASA/GSFC
Greenbelt, MD 20771

McDonnell-Douglas Space Systems
5301 Bolsa Ave
Huntington Beach, CA 92647

General Dynamics Commercial Launch Services
9444 Balboa Ave
Suite 200
San Diego, CA 92123

Martin Marietta Corporation
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Denver, CO 80201

MILSATCOM
SMC/MC
Los Angeles AFB, CA 90009-2960

NAVSTAR GPS JPO
SMC/CZ
PO Box 92960
Los Angeles AFB, CA 90009-2960

FEWS
SMC/MB
PO Box 92960
Los Angeles AFB, CA 90009-2960

Defense Meteorological Satellite Program
SMC/CI
PO Box 92960
Los Angeles AFB, CA 90009-2960

DARPA/ASTO
3701 N. Fairfax
Arlington, VA 22203

Defense Support Program
SMC/MJS
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Los Angeles AFB, CA 90009-2960

USSPACECOM
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USSPACECOM/J-3OC
Peterson AFB, CO 80914

HQ AFSPACECOM/DRSV
150 Vandenburg St
Peterson AFB, CO 80914-4790

HQUSAF/XORS
Pentagon
Washington D.C. 20330-1480

AFAF/SPACE
SAF/SN
1640 Air Force Pentagon
Washington D.C. 20330-1640

Launch Systems Division
SAF/AQSL
Pentagon
Washington D.C. 20330

HQUSAF/XORR
1480 Air Force Pentagon
Washington D.C. 20330-1480

SMC/CL
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Los Angeles AFB, CA 90009-2960

Titan SPO
SMC/ME
PO Box 92960
Los Angeles AFB, CA 90009-2960

Atlas II SPO
SMC/CLM
Building 100
Los Angeles AFB, CA 90009

Delta II SPO
SMC/CLZ
PO Box 92960
Los Angeles AFB, CA 90009-2960

Upper Stages SPO
SMC/CLU
PO Box 92960
Los Angeles AFB, CA 90009-2960

SAF/AQSL
Pentagon
Washington, D.C. 20330-1670

Appendix B

Characteristics and Capabilities Identified in Reports

America's Next Decades in Space (NASA, 1969)

1. Economic (37)
2. Flexible (37)
3. Versatile (37)
4. Low cost (37)
5. Reusable stage (39)
6. Nuclear propulsion stage (39)
7. Manned (48)
8. Short turn time (49)
9. Increased payload (54)

Hearings on Future Space Programs: 1981 (Stafford, 1981)

1. Efficiency (230)
2. Cost (230)
3. Maintainability (230)
4. Reliability (230)
5. Minimized turn around time (230)
6. Propulsion technology (231)
7. Manned (234)
8. Unmanned (234)
9. Expendable (234)

1986 Long-Range Program Plan (NASA, 1985)

1. Reliability (IV-2)
2. Low cost (IV-2)
3. Safety (IV-4)
4. Operability (IV-4)
5. Flexibility (IV-5)
6. Man-rateable (IV-5)
7. Modularity (IV-5)
8. Maintainability (IV-5)
9. Propulsion (IV-9)
10. Reusability (IV-16)
11. Lift capacity (IV-32)

Pioneering the Space Frontier (National Commission on Space, 1986)

1. Reliability (12)
2. Payload cost(12)
3. Crew and passenger considerations(13)
4. Expendability or reusability (107)
5. Adaptable for on-orbit servicing, maintenance, and repair (13)

6. Aerobraking (13)
7. Propulsion concerns (101)
8. Materials (101)
9. Structures (101)
10. Safety (101)
11. Engines (101)
12. Fuel Tanks (101)
13. Guidance (101)
14. Control (101)
15. Reduction of personnel needed to launch vehicle by automating vehicle checkouts (101)
16. Robustness (101)
17. Number of stages (101)
18. Payload-to-liftoff mass ratio (115)
19. Automated cargo handling and vehicle erection (115)
20. Rapid refueling (115)
21. All-weather capability (115)
22. Standardized payload and passenger modules (115)
23. Simple, standardized modular servicing (115)
24. Payload size (115)
25. Mass (115)

Leadership and America's Future in Space (Ride, 1987)

1. Heavy lift capacity (31)
2. Robust (34)
3. Man rateable (39)
4. Reliability (41)
5. Efficiency (58)

Launch Options for the Future: Buyer's Guide (U.S. Congress, Office of Technology Assessment, 1988a)

1. Cost (5)
2. Reliability (5)
3. Flight Rate (5)
4. Lift Capacity (5)
5. Resilience (21)
6. Launch costs/payload costs (21)
7. Payload size (21)
8. Environmental concerns (23)
9. Expendability (29)

Reducing Launch Operations Costs: New Technologies and Practices (U.S. Congress, Office of Technology Assessment, 1988b)

1. Cost (3)
2. Reliability (3)
3. Built-in test equipment (4)
4. Man-ratable (13)
5. Performance (15)
6. Safety (21)
7. Complexity (21)
8. Reusability (25)
9. Payload capacity (68)
10. Launch rate (26)
11. Maintainability (59)
12. Modularity (60)
13. Flexibility (68)
14. Resilient (68)
15. Operational availability (68)
16. Access probability (68)

National Space Launch Strategy (Defense Science Board, 1990)

1. Manned (6)
2. Unmanned (6)
3. Launch on Schedule (7)
4. Reliability (7)
5. Surge capability (7)
6. Military launch personnel (7)
8. Survivable (9)
9. Responsive (9)
10. Standardized interface (9)
11. Flexible (10)
12. Low cost (10)
13. Reduced processing time (15)

Access to Space: The Future of U.S. Space Transportation Systems (U.S. Congress, Office of Technology Assessment, 1990)

1. Reliability (3)
2. Operability (3)
3. Capacity (3)
4. Launch cost (3)
5. Safety (6)
6. Lift capacity (23)
7. Manned (23)
8. Responsiveness (25)

9. Maintainability (25)
10. Flexibility (25)
11. Launch support personnel (59)
12. Cargo only (69)
13. Redundant systems (71)
14. Standardized vehicle-cargo operations (71)
15. On-time performance (71)
16. Reusable (74)

Report of the Advisory Committee On the Future of the U.S. Space Program (*Report of the Advisory Committee*, 1990)

1. Payload capacity (7)
2. Launch costs (7)
3. Flexibility (32)
4. Efficiency (32)
5. Robustness (32)
6. Reliability (32)
7. Mission frequency (32)
8. Heavy lift capacity (33)
9. Launch support manpower (33)
10. The ability for the system to accept upgrades to existing components (33)
11. Expendability (33)
12. Unmanned but man rateable (33)

Aeronautics and Space Report of the President: 1989-1990 Activities (NASA, 1991)

1. Safe (53)
2. Efficient (53)
3. Reduced cost (53)
4. Expendable (53)
5. Partially reusable (53)
6. Fully reusable (53)
7. Robust (53)
8. Operationally simple (53)
9. Flexible (53)
10. Lightweight and durable thermal protection (53)
11. Lightweight and long-life cryogenic tanks (53)
12. Autonomous systems (53)
13. Reduced sensitivity to changes in launch conditions (53)

America at the Threshold (Synthesis Group, 1991)

1. Abort principles (18)
2. Crew considerations (18)
3. Launch costs (21)
4. Mission duration considerations (24)
5. Total mass (21)
6. Propellants (32)
7. Reliability (91)
8. Multiple levels of parallel redundant systems (91)
9. Payload capacity (64)
10. Type of propulsion system (64)
11. Lift capabilities (31)

National Space Policy Directive 4 (NSPD 4): National Space Launch Strategy (Bush, 1991)

1. Safety (1)
2. Reliability (1)
3. Launch costs (1)
4. Man-rateability (1)
5. Responsiveness (1)
6. Performance (1)
7. Reusability (2)
8. "Best-value" procurement (2)

The Future of the U.S. Space Launch Capability: A Task Group Report (Vice President's Space Policy Advisory Board, 1992)

1. Man-rateable (1)
2. Launch cost (1)
3. Performance (1)
4. Reliability (3)
5. Safety (3)
6. Reusability (3)
7. Lift capacity (3)
8. Flexibility (3)
9. Responsiveness (10)
10. Availability (10)
11. Operability (10)

Final Report to the President on the U.S. Space Program (National Space Council, 1993)

1. Launch cost (5)
2. Operability (5)
3. Responsiveness (5)

4. Reusability (5)
5. Safety (5)
6. Performance (6)
7. Reliability (6)
8. Flexibility (6)
9. Efficiency (6)
10. Robustness (6)
11. Man-rateable (6)

Appendix C

Preliminary Survey

Background

The attached survey will be used to gather data for research being conducted in conjunction with a Master's thesis at the Air Force Institute of Technology. The researchers intend to compare space launch vehicle users and providers' perceptions of which space launch vehicle characteristics and capabilities are critical. This research is further divided into the launch categories: military, commercial, and civil.

Space Launch Vehicle Characteristics and Capabilities

In order to prepare this questionnaire, the researchers first had to obtain a listing of space launch vehicle characteristics and capabilities. Despite extensive research, a comprehensive list was not available.

The researchers reviewed ten reports commissioned between the years 1986 and 1992 by the President, Vice President, U.S. Congress, Department of Defense, and NASA. Although none of the reports contained comprehensive lists, the authors of these reports identified several characteristics and capabilities of space launch vehicles. Those characteristics and capabilities discussed in more than one report became the basis for this survey.

Purpose of Pretesting the Survey

Administering a draft of the survey to space launch vehicle experts such as yourself will serve as a pretest to ensure the usefulness of the final survey. The researchers ask that while completing the survey you also evaluate the clarity and completeness of the survey's directions, questions, and definitions. Feel free to suggest any improvements. If you have any comments, please write them on the survey. Your responses will be completely confidential, and the researchers do **not** ask you to provide your name.

Your participation in pretesting the survey is greatly appreciated and will contribute immensely to the success of this research. Thank you for your cooperation.

DAWSON S. OSLUND, Capt, USAF
Graduate Student
AF Institute of Technology

MARK W. SHAFER, Capt, USAF
Graduate Student
AF Institute of Technology

SURVEY

Directions

The following list of space launch vehicle characteristics and capabilities were compiled from those identified in ten commissioned reports. Please indicate your perception of the criticality of the following space launch vehicle characteristics and capabilities on a scale ranging from 1 being **NOT CRITICAL** to 5 being **CRITICAL** (with 3 being considered a neutral response). For purposes of standardization, each term was operationally defined by the researchers. Please indicate your perceptions based on those definitions. Feel free to comment in the space provided.

CHARACTERISTIC/CAPABILITY	**Not Critical** 1 2 3 4 5 **Critical**
1. **Launch Cost**-*the cost to place a payload into the desired orbit* Comments:______________________	1 2 3 4 5
2. **Reliability**-*the percentage of payloads delivered to the correct orbit at the scheduled time* Comments:______________________	1 2 3 4 5
3. **Lift Capacity**-*the maximum total payload weight the vehicle can place in orbit* Comments:______________________	1 2 3 4 5
4. **Man Rateable**-*possessing sufficient reliability, redundancy, and robustness to minimize catastrophic failure* Comments:______________________	1 2 3 4 5
5. **Reusability**-*ability to recover and relaunch either the entire vehicle or a core module of the vehicle* Comments:______________________	1 2 3 4 5
6. **Efficiency**-*the ratio of actual performance divided by the theoretical maximum for all design criteria* Comments:______________________	1 2 3 4 5
7. **Payload size**-*maximum cubic size of a payload that the vehicle is capable of transporting to orbit* Comments:______________________	1 2 3 4 5

	Not Critical			Critical

8. **Robustness**-*ability of a system to tolerate failure or adverse circumstances while continuing to operate* 1 2 3 4 5
Comments:____

9. **Safety**-*precautions taken to ensure safe return of the crew* 1 2 3 4 5
Comments:____

10. **Maintainability**-*ability to troubleshoot (including integrated diagnostics) and replace components throughout the vehicle regardless of vehicle location with minimal impact on other systems* 1 2 3 4 5
Comments:____

11. **Flexibility**-*ability for the vehicle to deploy a variety of payloads to different orbits on different missions* 1 2 3 4 5
Comments:____

12. **All-weather capability**-*ability to launch, operate, and recover vehicle despite weather conditions at the launch facility or downrange* 1 2 3 4 5
Comments:____

13. **Environmental impact**-*the amount of damage inflicted by the vehicle during launch and recovery--to include propellants, exhaust, and noise* 1 2 3 4 5
Comments:____

14. **Minimized launch support personnel**-*the number of people required to prepare, launch, monitor operations, and recover the vehicle for each launch* 1 2 3 4 5
Comments:____

15. **Mass (Gross Liftoff Weight)**-*total quantity of matter of the vehicle, payload, and fuel prior to launch* 1 2 3 4 5
Comments:____

16. **Modularity**-*design of the vehicle allowing additional stages or strap-on boosters to be added to the core of the vehicle* 1 2 3 4 5
Comments:____

	Not Critical				Critical
17. **Operability**-*calendar time required to prepare and service a vehicle in preparation for launch*	1	2	3	4	5

Comments:______________________________

18. **Performance**-*weight delivered to orbit for a given gross takeoff weight*	1	2	3	4	5

Comments:______________________________

19. **Propulsion**-*all devices imparting impulse to the vehicle*	1	2	3	4	5

Comments:______________________________

20. **Responsiveness**-*ability to expedite launch preparation in response to short notice tasking*	1	2	3	4	5

Comments:______________________________

21. **Resilience**-*ability of the system to recover from setbacks and continue launches despite a failure*	1	2	3	4	5

Comments:______________________________

22. **Standardized payload interface**-*design of cargo bay requiring payloads to meet standardized configurations (to include software interface)*	1	2	3	4	5

Comments:______________________________

23. Do you consider yourself a launch vehicle user or provider?

____

24. In which of the following sectors are you located: commercial, civil, or military?

____

25. What additional characteristics or capabilities do you consider as necessary for space launch vehicles to possess?

____

Appendix D

Survey Introductory Letter

Name
Title
Address
City, State, Zip

Salutation

A continuing topic of interest in the space launch arena revolves around the design of space launch vehicles. Over the past several years a number of studies have been conducted reviewing the U.S. space program which included discussions of space launch vehicles. The reports of these studies enumerated a large number of launch vehicle characteristics and capabilities. However, the discussions of characteristics and capabilities within the reports revealed little continuity among the studies.

USAF Captains Dawson Oslund and Mark Shafer are researching launch vehicle characteristics and capabilities to identify which are considered critical for launch vehicle success, as part of a master's thesis at the School of Systems and Logistics at the Air Force Institute of Technology. Included in their research, Captains Oslund and Shafer will compare which characteristics and capabilities launch service providers and launch service users consider critical. This study is being co-sponsored by the National Contract Management Association; the Chief of the Launch Systems Division, Assistant Air Force Secretary of Acquisitions, Col Charles R. Banta; and Deputy Associate Director for Commercial Space Policy and International Affairs, Office of Commercial Space Transportation, Mr Carl S. Rappaport.

As part of their thesis, Capt Oslund and Capt Shafer will conduct a survey with a selected group of experts in the area of space launch. This group of experts will include members of the military, commercial, and civil space programs to facilitate comparison. Because of your expertise as either a provider or user of space launch vehicles, Capt Oslund and Capt Shafer request your input in their research.

In the near future, you will receive their survey through the mail. Your response will be greatly appreciated.

If you have any questions regarding the study, please contact Capt Oslund at (513)427-1897 or Capt Shafer at (513)236-5621.

WILLIAM C. PURSCH, Ph.D.
Functional Director for Research and Grants
National Contract Management Association

Appendix E

Survey Package

Name
Title
Address
City, Zip Code

Salutation

As an expert in the field of space launch, you are being asked to provide your inputs to the selection of critical space launch vehicle characteristics and capabilities. You should have received a letter about one week ago explaining the arrival of this survey. Here's a reminder of the survey's purpose.

As graduate students at the Air Force Institute of Technology, we've selected space launch vehicles as our topic area for a joint masters thesis. We're trying to identify whether or not the critical characteristics and capabilities of medium-lift to heavy-lift space launch vehicles identified by vehicle providers are similar or different to those identified as critical by users.

In addition, we'll compare and contrast the responses to this survey among three categories of users and designers: military, commercial, and civil. This will help identify any differences among the categories.

This research is being co-sponsored by the Chief of the Launch Systems Division, Assistant Air Force Secretary (Acquisition); the Deputy Associate Director for Commercial Space Policy and International Affairs, Office of Commercial Space Transportation; and the National Contract Management Association. Your participation in the following survey is greatly appreciated and will contribute immensely to the success of this research. Thank you for your cooperation.

DAWSON S. OSLUND, Capt, USAF
Graduate Student
AF Institute of Technology

MARK W. SHAFER, Capt, USAF
Graduate Student
AF Institute of Technology

SURVEY INTRODUCTION

Background

The researchers intend to compare space launch vehicle users and providers' perceptions of which space launch vehicle characteristics and capabilities are critical. This research is further divided into the launch categories: military, commercial, and civil.

Space Launch Vehicle Characteristics and Capabilities

In order to prepare this questionnaire, the researchers first had to obtain a listing of space launch vehicle characteristics and capabilities. Despite extensive research, a comprehensive list was not available.

The researchers reviewed ten reports commissioned between the years 1985 and 1992 by the President, Vice President, U.S. Congress, Department of Defense, and NASA. Although none of the reports contained comprehensive lists, the authors of these reports identified several characteristics and capabilities of space launch vehicles. Those characteristics and capabilities discussed in more than one report became the basis for this survey.

Purpose of the Survey

This survey will provide the data necessary to compare perceptions of launch vehicle users and providers concerning critical space launch vehicle characteristics and capabilities. Additional comparison will also be made concerning the three categories of space launch: military, commercial, and civil.

Please feel free to use the space provided for any additional comments. In order to permit a high level of control and maintain your confidentiality, a control number has been assigned to your survey. Only Capt Oslund and Capt Shafer will be able to match your responses with your identity. The enclosed self-addressed stamped envelope is provided for your convenience.

If you have any questions about this survey, please feel free to call either Capt Dawson Oslund at (513)427-1897 or Capt Mark Shafer at (513)236-5621. Please send your responses to:

Capt Dawson Oslund	or FAX c/o	Dr. Douglas Goetz
1435 Sanzon Dr.		AFIT/LSP
Fairborn, OH 45324		Comm: (513)476-4289

Once again, thank you for your time.

SURVEY

Directions

The following list of space launch vehicle characteristics and capabilities were compiled from those identified in ten commissioned reports. Please indicate your perception of the criticality of the following space launch vehicle characteristics and capabilities according to the following scale:

1 -- Very Uncritical
2 -- Uncritical
3 -- Somewhat Uncritical
4 -- Neutral
5 -- Somewhat Critical
6 -- Critical
7 -- Very Critical

For purposes of standardization, each term was operationally defined by the researchers. Please indicate your perceptions based on those definitions. Feel free to comment in the space provided.

CHARACTERISTIC/CAPABILITY	Very Uncritical						Very Critical
1. **Launch cost**-*the cost to place a payload into the desired orbit*	1	2	3	4	5	6	7
2. **Reliability**-*the percentage of payloads delivered to the correct orbit at the scheduled time*	1	2	3	4	5	6	7
3. **Lift capacity**-*the maximum total payload weight the vehicle can place in a specific orbit*	1	2	3	4	5	6	7
4. **Man rateable**-possessing sufficient reliability, *redundancy, and robustness to minimize catastrophic* failure	1	2	3	4	5	6	7
5. **Reusability**-*ability to recover and relaunch either the entire vehicle or a core module of the vehicle*	1	2	3	4	5	6	7

1. Comments: ______________________________

2. Comments: ______________________________

3. Comments: ______________________________

4. Comments: ______________________________

5. Comments: ______________________________

	Very Uncritical						Very Critical
6. **Efficiency**-*effective use of resources (ie. manpower and fuel)* Comments:______	1	2	3	4	5	6	7
7. **Payload size**-*maximum payload length, width, and height dimensions that will fit in the vehicle's cargo bay* Comments:______	1	2	3	4	5	6	7
8. **Robustness**-*ability of a vehicle to tolerate the failure of a system(s) or adverse circumstance(s) and continue to operate* Comments:______	1	2	3	4	5	6	7
9. **Safety**-*precautions taken to protect from hazards the crew, payload, ground crew, launch facilities, and third party personnel* Comments:______	1	2	3	4	5	6	7
10. **Maintainability**-*ability to troubleshoot (including integrated diagnostics) and replace components throughout the vehicle regardless of vehicle location with minimal impact on other systems* Comments:______	1	2	3	4	5	6	7
11. **Flexibility**-*ability for the vehicle to deploy a variety of payloads to different orbits on different missions* Comments:______	1	2	3	4	5	6	7
12. **All-weather capability**-*ability to launch, operate, and recover vehicle despite weather conditions at the launch facility or downrange* Comments:______	1	2	3	4	5	6	7
13. **Environmental impact**-*the amount of damage inflicted by the vehicle during launch and recovery--to include propellants, exhaust, and noise* Comments:______	1	2	3	4	5	6	7

	Very Uncritical						Very Critical
14. **Launch support personnel required**-*the number of people required to prepare, launch, monitor operations, and recover the vehicle for each launch*	1	2	3	4	5	6	7
15. **Gross liftoff weight**-*total mass of the vehicle, payload, and fuel prior to launch (ie. the total mass that the engines must lift)*	1	2	3	4	5	6	7
16. **Modularity**-*design of the vehicle allowing additional or upgraded stages or strap-on boosters to be added to the core of the vehicle*	1	2	3	4	5	6	7
17. **Operability**-*calendar time required to prepare and service a vehicle in preparation for launch*	1	2	3	4	5	6	7
18. **Performance**-*thrust-to-weight ratio*	1	2	3	4	5	6	7
19. **Propulsion**-*the type of propellant used by the engines (ie. liquid or solid)*	1	2	3	4	5	6	7
20. **Responsiveness**-*ability to expedite launch preparation in response to short notice tasking*	1	2	3	4	5	6	7
21. **Resilience**-*ability of the launch vehicle program to recover from setbacks and continue launches despite a vehicle failure*	1	2	3	4	5	6	7
22. **Standardized payload interface**-*design of cargo bay requiring payloads to meet standardized configurations (to include software interface)*	1	2	3	4	5	6	7

Comments:

23. List what you perceive to be the three **most critical** space launch vehicle characteristics and/or capabilities.

24. List what you perceive to be the three **least critical** space launch vehicle characteristics and/or capabilities.

25. List and briefly define any additional characteristics or capabilities that you consider necessary for space launch vehicles to possess.

Appendix F

Follow-up Letters

Name
Title
Address
City, State, Zip

Salutation,

Thank you for participating in our study of the critical characteristics and capabilities of space launch vehicles. Your response is a critical part of our research. If you have any questions concerning the survey or the research, please contact one of the following individuals.

Capt Mark Shafer DSN (messages) 785-8989 Home (513) 236-5621
Capt Dawson Oslund DSN (messages) 785-8989 Home (513) 427-1897

Once again, we would like to thank you for your participation in this research.

DAWSON S. OSLUND, Capt, USAF
Graduate Student
AF Institute of Technology

MARK W. SHAFER, Capt, USAF
Graduate Student
AF Institute of Technolgy

Name
Title
Address
City, Zip Code

Salutation

Thank you for participating in our study of the critical characteristics and capabilities of space launch vehicles. Hopefully you have received the survey, and have had a chance to consider it. Your response is a critical part of our research. If you have any questions concerning the survey or the research, please contact one of the following individuals.

Capt Mark Shafer DSN (messages) 785-8989 Home (513) 236-5621
Capt Dawson Oslund DSN (messages) 785-8989 Home (513) 427-1897

Once again, we would like to thank you for your participation in this research.

DAWSON S. OSLUND, Capt, USAF
Graduate Student
AF Institute of Technology

MARK W. SHAFER, Capt, USAF
Graduate Student
AF Institute of Technolgy

Appendix G

SAS Program and Data Set

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proc means data=thesis;
  var cost reliab lift_cap man_rate reusable effic payld_sz
    robust safety maintain flexible all_weat environ personel
    glow modular operable perform propulsn response resilien
    standard;
proc sort data=thesis;
  by field;
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proc corr;
  by field;
  var cost reliab lift_cap man_rate reusable effic payld_sz
    robust safety maintain flexible all_weat environ personel
    glow modular operable perform propulsn response resilien
    standard;
proc sort;
  by sector;
proc corr;
  by sector;
  var cost reliab lift_cap man_rate reusable effic payld_sz
    robust safety maintain flexible all_weat environ personel
    glow modular operable perform propulsn response resilien
    standard;
proc sort;
  by class;
proc corr;
  by class;
  var cost reliab lift_cap man_rate reusable effic payld_sz
    robust safety maintain flexible all_weat environ personel
    glow modular operable perform propulsn response resilien
    standard;
proc glm;
  class field sector class;
  model cost=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model reliab=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model lift_cap=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model man_rate=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model reusable=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model effic=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model payld_sz=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model robust=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model safety=field sector class;
  means field sector class / tukey alpha=0.10;
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proc glm;
  class field sector class;
  model maintain=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model flexible=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model all_weat=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model environ=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model personel=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model glow=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model modular=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model operable=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model perform=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model propulsn=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model response=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model resilien=field sector class;
  means field sector class / tukey alpha=0.10;
proc glm;
  class field sector class;
  model standard=field sector class;
  means field sector class / tukey alpha=0.10;
proc corr nomiss alpha;
  var cost reliab lift_cap man_rate reusable effic payld_sz
    robust safety maintain flexible all_weat environ personel
    glow modular operable perform propulsn response resilien
    standard;
run;
```

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<u>Vitae</u>

Captain Dawson S. Oslund was born on 9 September 1964 in Naha, Okinawa. In 1982, he graduated from the Frankfurt International School in Frankfurt, Germany. He was a distinguished graduate from the U.S. Air Force Academy in 1987 with a Bachelor of Science Degree in Engineering Mechanics and received a regular commission into the USAF. From January 1988 to February 1992, he served as aircraft maintenance officer for the 9th Strategic Reconnaissance Wing at Beale AFB, CA, holding OIC positions in the U-2, SR-71, and KC-135 maintenance squadrons. He also served as Chief of Logistics for the 1704th Provisional Reconnaissance Squadron, from January to April 1991, in Saudi Arabia. After attending Squadron Officer's School en route, Captain Oslund entered the School of Logistics and Acquisition Management, Air Force Institute of Technology, in May 1992, as a master's candidate in the Logistics Management Program. In January 1993, he was inducted into the National Honorary Fraternity for Management, Sigma Iota Epsilon. In October 1993, Captain Oslund will move to Vienna, Austria to study at the University of Vienna for three years as an Olmsted scholar.

Permanent Address: 1 Benjamin Court
Parsippany, New Jersey 07054

Captain Mark W. Shafer was born on 6 November 1965 in Chicago, Illinois. He graduated from Kickapoo High School in Springfield, Missouri in 1983. He graduated from the U.S. Air Force Academy with a Bachelor of Science Degree and received a regular commission in the USAF in 1987. Upon completion of the Aircraft Maintenance Officer's Course at Chanute Air Force Base, Illinois, he was assigned to the 354th Fighter Wing, Myrtle Beach Air Force Base, South Carolina. From January 1988 through March 1989, he served as the Officer-in-Charge (OIC) of the Component Repair Squadron's Propulsion Branch. He was the Assistant OIC of the 356th Aircraft Maintenance Unit (AMU) from April 1989 until May 1991, and completed his tour as the OIC of the 355th AMU. In May 1992, Captain Shafer entered the School of Logistics and Acquisition Management, Air Force Institute of Technology, as a master's candidate in the Acquisition Logistics Program. In January 1993, he was inducted into the National Honorary Fraternity for Management, Sigma Iota Epsilon. Upon graduation from AFIT, Capt Shafer will be assigned to the C-17 System Program Office at Wright-Patterson AFB.

Permanent Address: 6446 N. Merrimac
Kansas City, MO 64151

REPORT DOCUMENTATION PAGE

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12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*) This study compares spacelift vehicle users' and providers' perceptions of critical spacelift vehicle characteristics and capabilities. The researchers conducted a mail survey of military, commercial, and civil spacelift vehicle users and providers to determine a criticality rating for each of the 22 characteristics and capabilities identified through a literature review. Primary results of the study indicate: 1) the three most critical characteristics and capabilities are reliability, launch cost, and resilience; 2) the three least critical characteristics and capabilities are man-rateable, reusability, and gross lift-off weight; 3) only launch cost has a significantly different mean criticality rating among spacelift vehicle users and providers; and 4) 13 of the 22 characteristics and capabilities have significantly different mean criticality ratings between military and commercial respondents. The researchers conclude that differences between users' and providers' perceptions are inconsequential, but further study of military and commercial perceptions is necessary.

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Prescribed by ANSI Std. Z39-18
298-102

AFIT Control Number AFIT/GLM/LAR/93S-32

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The purpose of this questionnaire is to determine the potential for current and future applications of AFIT thesis research. Please return completed questionnaires to: DEPARTMENT OF THE AIR FORCE, AIR FORCE INSTITUTE OF TECHNOLOGY/LAC, 2950 P STREET, WRIGHT PATTERSON AFB OH 45433-7765

1. Did this research contribute to a current research project?

   a. Yes b. No

2. Do you believe this research topic is significant enough that it would have been researched (or contracted) by your organization or another agency if AFIT had not researched it?

   a. Yes b. No

3. The benefits of AFIT research can often be expressed by the equivalent value that your agency received by virtue of AFIT performing the research. Please estimate what this research would have cost in terms of manpower and/or dollars if it had been accomplished under contract or if it had been done in-house.

   Man Years ______________ $ ______________

4. Often it is not possible to attach equivalent dollar values to research, although the results of the research may, in fact, be important. Whether or not you were able to establish an equivalent value for this research (3, above) what is your estimate of its significance?

   a. Highly Significant b. Significant c. Slightly Significant d. Of No Significance

5. Comments

______________________________ ______________________________

Name and Grade Organization

______________________________ ______________________________

Position or Title Address